■ Interagency Ecological Program for the San Francisco Estuary ■

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Of Interest to Managers

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Quarterly Highlights

2002 Summer Townet Survey. Marade Bryant (DFG, page 3) describes the outcome of the survey: some of the lowest juvenile striped bass catches ever and no calculable value for the Striped Bass 38.1-mm Index. The delta smelt index for 2002 was 4.7, higher than the 2001 value of 3.5.

Delta smelt recovery criteria satisfied. Kevin Fleming (DFG, page 5) summarizes findings of the 2002 Fall Midwater Trawl and explains why the USFWS recovery criteria for Delta smelt have been reached despite the recovery index taking its fifth lowest value since 1967.

Contributed Papers

Predicting Juvenile Chinook Emigration. From a review of historical monitoring data, Erin Chappell (DWR, page 12) adduces uses of environmental variables for short-term prediction of juvenile chinook salmon emigration from the monitored upper tributaries and Sacramento River. If developed, better short-term prediction of juvenile salmon take could improve management of water project operations.

***Microcystis* Blooms.** Peggy Lehman and Scott Waller (DWR, page 18) describe the characteristics of and potential mischief caused by the bluegreen alga *Microcystis aeruginosa*, which caused blooms in portions of the Delta in 2002. *Microcystis* releases a toxin during decomposition that might pose a drinking water quality threat under some conditions.

Shallow Water Predator-Prey Dynamics. Matt Nobriga (DWR, page 19) and others report on an ongoing study of the ecological relationships between piscivorous fishes and their prey in the Estuary, including early information on common predator diet and prey abundance differences over space and time during 2000-2001. Interestingly, striped bass diets have changed substantially since the 1960s. By elucidating likely predation pressures on fish species of management concern in various habitats, this study may help guide restoration design.

Hydrologic Variation in the Yolo Bypass. Using a hydrologic model, Ted Sommer (DWR, page 27) and others found extensive temporary flooding of the Yolo Bypass after even modest high-flow events in the Sacramento River. During floods, average velocities were lower in the inundated areas of the bypass than in the river itself, while hydraulic residence times were higher. They discuss why creation of seasonally flooded shallow water habitat may be a key issue in restoration design.

CALFED Activities

Zach Hymanson and Sam Luoma (CALFED, page 32) summarize current CALFED Science Program activities and interests.

Scientific Community News

New USFWS Stockton Office Leader. We are pleased to welcome Russ Bellmer as the new Project Leader for the Stockton USFWS office (page 35).

Meeting Review

Mitten Crab Workshop. Deborah Rudnick (UCB, page 35) summarizes mitten crab monitoring results for 2002 and the events of the 2002 mitten crab workshop.

On the Horizon

Larval Fish Symposium. An IEP-sponsored symposium on the early life history of fishes in the San Francisco Estuary and Watershed will be presented at the AFS Larval Fish Conference in August 2003 at UC Santa Cruz (page 38). A proceedings volume containing twenty papers will be published by the AFS. The symposium will summarize decades of fish early life stage work in the estuary and watershed, and should be of great interest to fish biologists working in this system.

Lower American River Science Conference. The Lower American River Science Conference will convene at CSU Sacramento June 5 and 6, 2003 (page 39). There will be fish, groundwater, and weather sessions that should be of wide interest to the scientific community.

IEP QUARTERLY HIGHLIGHTS

July-December 2002

Summary Townet Survey

Marade Bryant (DFG), mbryant@delta.dfg.ca.gov

The Summer Townet Survey (TNS) produces an annual age-0 abundance index (the 38.1-mm Index) for striped bass, *Morone saxatilis,* and an annual age-0 abundance index for delta smelt, *Hypomesus transpacificus*. The delta smelt index, calculated differently than the 38.1-mm Index, uses the mean of the first two surveys instead of interpolating between the two surveys that bracket a striped bass mean length of 38.1 mm. The 38.1-mm index was not calculated for striped bass in 2002. The delta smelt index for 2002 was 4.7, an increase over last year's 3.5.

The striped bass 38.1-mm Index was not calculated as a result of consistently small fish, record low catches, and, ultimately, a boat breakdown partway through survey 5. The average size of striped bass remained small during the first two surveys (17.5 mm and 18.9 mm, respectively); then, after a large increase in size for the third survey, average size decreased between the third and fourth surveys, from 32.6 mm to 29.9 mm. A fifth survey was attempted with hope the average length of 38.1 mm would be exceeded despite low catches in the previous two surveys (Table 1). Ten stations were not sampled during survey 5 due to boat breakdowns — including those in Montezuma Slough and the stations within and downstream of Suisun Bay — making an index calculation infeasible even though the average size of striped bass prior to the breakdown exceeded 38.1 mm. Even if all stations had been sampled and 38.1 mm had been exceeded, an index calculated with the record low catches might not be representative of the year class since catches could be due to random chance. The lack of fish was noticeable in surveys 3 and 4, with only 33 striped bass caught during survey 3, and 17 during survey 4. These are the lowest striped bass numbers recorded for total catch in a survey for the TNS. The total striped bass catch for 2002 dropped 70% from 2001, and 83% from 2000.

Striped bass moved downstream as the summer progressed (Table 2). During survey 1 (June 16-20), the majority of striped bass were caught in the South Delta (32%), and in the lower San Joaquin River (46%) during survey 2 (June 29-July 3). Survey 3 (July 14-18) and survey 4 (July 29-August 2) showed the majority in the Sacramento River (35% and 53%, respectively). No striped bass were caught in the South or East Delta during surveys 4 and 5.

The majority of delta smelt were caught in the Sacramento River every survey (Table 2). Survey 3 showed equal numbers in the Sacramento River and Suisun Bay, but the percentage dropped in Suisun Bay as it increased in the Sacramento River during survey 4. Complete numbers are not available for survey 5.

Table 1 Mean length, sample size, and survey indices for striped bass and delta smelt during townet surveys 1-5, 2002.

	Survey 1	*Survey 2*	*Survey 3*	*Survey 4*	*Survey 5*[a]
Striped Bass					
Mean length (mm FL)	17.5	18.9	32.6	29.9	41.3
N	134	117	33	17	6
Survey index	2.1	2.0	0.6	0.05	[a]
Delta Smelt					
Mean length (mm FL)	38	38	40	38	46
N	196	83	54	44	87
Survey index	6.6	2.9	2.0	1.9	3.4

[a] Incomplete Survey

Table 2 Percentages of survey index by area for striped bass and delta smelt for townet surveys 1-5, 2002

Species and area	*Survey 1*	*Survey 2*	*Survey 3*	*Survey 4*	*Survey 5*
Striped Bass					
Montezuma Slough	11.0	21.0	23.0	38.0	N/S
Suisun Bay	0.0	3.0	25.0	0.0	29.0[a]
Sacramento River	12.0	8.0	35.0	53.0	14.0
San Joaquin River	20.0	46.0	13.0	9.0	57.0
East Delta	25.0	13.0	2.0	0.0	0.0
South Delta	32.0	9.0	2.0	0.0	0.0
Delta Smelt					
Montezuma Slough	0.0	0.0	0.0	0.0	N/S
Suisun Bay	11.0	17.0	49.0	23.0	24.0[a]
Sacramento River	84.0	78.0	49.0	77.0	76.0
San Joaquin River	5.0	5.0	2.0	0.0	0.0
East Delta	0.0	0.0	0.0	0.0	0.0
South Delta	0.0	0.0	0.0	0.0	0.0

[a] Not all stations sampled in area

Population Indices and Estimates Seminar

Mike Chotkowski (USBR), chotski@pacbell.net

On November 22, 2002, the Management Team convened a panel of speakers to discuss the differences between population indices and actual size estimates. Population indices are statistics used to summarize monitoring data. Actual size estimates are indices that have the special property that they estimate the number (or, usually equivalently, density) of organisms in a region of interest. Strictly speaking, actual size estimates require random sampling; however, there are gray areas where, as we discussed, fixed-station sampling may be used provisionally to estimate population size. Such applications are likely to be controversial, as the discussion at this event illustrates. Understanding the differences between ordinary indices and actual estimates, and their overlapping uses, is important to users of monitoring data and to managers who must maintain long-term monitoring programs. An annotated transcript of the event is in preparation and will be posted in “report” format to the IEP website in February or March 2003.

Speakers at the event were:

1. Mike Chotkowski, USBR. Session introduction.
2. Kevin Fleming, DFG. Local use of indices in stock management, status and trends assessment, and recovery criteria.
3. Wim Kimmerer, SFSU. When are indices not enough? (Also: a different approach to estimating take at the pumps.)
4. Bryan Manly, WEST, U. Otago. Estimating actual population size.
5. David Kohlhorst, DFG. Mark-recapture estimation of striped bass and white sturgeon population sizes in the Estuary.
6. B.J. Miller. Delta smelt population size estimation.

Splittail Early Life History Studies

Fred Feyrer (DWR), Linda Rivard (DWR), Ted Sommer (DWR), and Randy Baxter (DFG), ffeyrer@water.ca.gov

The first year of field sampling for this study was completed this summer. In total over 2,500 individual young-of-year splittail were collected from the San Joaquin River, Sacramento River, Sutter Bypass and Butte Creek, Yolo Bypass, Delta, Cosumnes River, Napa River, and Petaluma River. All of the samples have been processed and laboratory work examining otoliths and gut contents will begin soon. The data obtained during this study will provide information on the habitat associations, hatch dates, growth rates, and feeding habits of young-of-year splittail.

Fall Midwater Trawl and the Delta Smelt Recovery Criteria

Kevin Fleming (DFG), kfleming@delta.dfg.ca.gov

The US Fish and Wildlife Service's Delta Native Fishes Recovery Plan (1995) set forth a series of conditions deemed appropriate for the consideration of delta smelt as recovered. These conditions included benchmarks for both abundance and distribution and were based upon historic (pre-decline) data. The plan requires that the preset conditions be met over a five-year span; this roughly corresponds to five generations. A further requirement is that during the five-year span there must be two consecutive years of extreme water year types.

The plan makes use of the abundance and distribution data from DFG's Fall Midwater Trawl Survey (FMWT). The recovery abundance index calculated in the plan differs from the FMWT index in that it is uses a subset of the sampling stations and includes only the September and October raw catches. The abundance criteria set forth in the plan are as follows: abundance must meet or exceed 239 in two of five years and the two-year running average must never fall below 84.

The plan divides the estuary into three major zones. There are 11 stations that represent North Central Delta, 9 representing Sacramento River and Montezuma Slough, and 15 representing Suisun Bay. The distribution criteria are based upon the collection of smelt within these zones during September and October sampling. For each zone there are a minimum number of stations at which smelt must be collected for the criteria to be met. The plan calls for site criteria to be met (1) in all zones in two out of five years, (2) in at least two zones in one of the remaining three years, and (3) in at least one zone for the remaining two years.

The last recovery station for 2002 was sampled on October 16 and the recovery index was set at 33 (Figure 1). This represents the fifth lowest recovery index since 1967. However, the relatively high 2001 index of 314 assured that the two-year running average requirement would be met. Additionally, in terms of the five-year span requirement, the five-year span includes three years of indices over 239.

The 2002 distribution criteria for recovery was only met for zone B, where smelt were collected at six out of the nine recovery stations within the zone. Although the distribution criteria were only met for one zone, it was all that was required by the plan because of the previous four years.

The final requirement of "extreme" consecutive water years was also met. The Sacramento River hydrologic indices for both 2001 and 2002 were classified as "Dry." So, despite relatively low abundance and limited distribution, the delta smelt have reached the five-year recovery criteria as set forth in the plan.

Reference

US Fish and Wildlife Service. 1995. Sacramento-San Joaquin Delta native fisheries recovery plan. US Fish and Wildlife Service, Portland, Oregon.

Criteria / Year	Distribution Criteria: North Central Delta	Distribution Criteria: Sacramento River and Montezuma Slough	Distribution Criteria: Suisun Bay	Abundance Criteria: Recovery Index	Abundance Criteria: 2yr average	Water Year Type[a]
	2 of 11	5 of 9	6 of 15			
1967	2	8	6	139	na	Wet
1968	8	6	9	251	195	Below
1969	0	7	11	128	190	Wet
1970	7	8	12	589	359	Wet
1971	8	7	13	352	471	Wet
1972	9	8	12	551	452	Below
1973	4	9	9	305	na	Above
1974	Not sampled					Wet
1975	5	5	12	239	272	Wet
1976	2	5	2	22	131	Critical
1977	5	5	0	146	84	Critical
1978	0	6	11	108	127	Above
1979	Not sampled					Below
1980	3	8	10	312	na	Above
1981	0	6	8	78	195	Dry
1982	1	6	6	37	58	Wet
1983	0	4	5	17	27	Wet
1984	0	3	9	51	34	Wet
1985	0	3	2	29	40	Dry
1986	1	5	10	70	50	Wet
1987	1	4	1	72	71	Dry
1988	0	3	2	67	70	Critical
1989	4	5	6	76	72	Dry
1990	0	6	4	81	79	Critical
1991	3	6	4	171	126	Critical
1992	1	5	0	26	99	Critical
1993	4	6	12	400	213	Above
1994	1	5	1	19	210	Critical
1995	1	7	14	252	136	Wet
1996	2	4	8	28	140	Wet
1997	1	4	3	62	45	Wet
1998	0	7	12	169	116	Wet
1999	5	7	9	322	246	Wet
2000	3	9	10	265	294	Above
2001	3	8	6	314	290	Dry
2002	1	6	3	33	174	Dry

[a] based upon Sacramento River Index

Abundance Criteria:

Delta smelt abundance must meet or exceed 239 in 2 out of 5 years and the 2-year running average must never fall bellow 84

If any of these conditions are not met, the five-year recovery period will start again.

Distribution Criteria:

1) site criteria must be met in all zones 2 out of 5 years

2) in at least two zones in 1 of the remaining 3 years

3) in at least one zone for the remaining 2 years.

Figure 1 Delta smelt recovery index

Benthic Monitoring, Summer 2002

Karen Gehrts (DWR), kagehrts@water.ca.gov

Benthic monitoring is conducted at ten sampling sites distributed throughout the major habitat types within the Bay-Delta system. Bay-Delta Monitoring and Analysis Section staff collect four bottom-grab samples and one sediment sample monthly at all sites. The grab samples are analyzed in the laboratory to identify organisms to genus (and species when possible), and to enumerate all organisms collected. Sediment samples are analyzed to determine substrate composition. The field methodology for the collection of benthic macroinvertibrates is summarized in *Standard Methods for the Examination of Water and Wastewater, 20th ed. 1998.*

The Environmental Monitoring Program (EMP) maintains a database of 284 benthic organisms identified within the upper San Francisco Estuary. The benthic database is dynamic because it is regularly peer reviewed and updated. When a new organism is found at any of the sampling stations, the organism is identified to the species taxonomic level when possible and added to the database. In addition, the taxonomic names of organisms on the list are updated when sufficient evidence is produced to warrant such changes. During the summer of 2002, a new benthic species was added to the database, one species was removed, and the names of seven organisms were revised (Bousfield 1997). A new polycheate annelid, *Myxicola infundbulum*, was found at Station D41 in San Pablo Bay in July, and the gammarid amphipod, *Monocorophium oaklandense*, was made synonymous with *Monocorophuim insidiosum*. As a result, all records of *M. oaklandense* are now listed as *M. insidiosum.* Finally, Table 1 lists the seven benthic organisms undergoing revisions in identification.

Reference

Bousfield EL, Hoover PM. 1997. The amphipod superfamily Corophioidea on the Pacific Coast of North America, Part V. Family Corophiinae, new subfamily. Systematics and distributional ecology. Amphipacifica 2(3): 67-139.

Table 1 Benthic organisms undergoing revisions in identification

Phylum	*Family*	*Genus*	*Species*	*New Phylum*	*New Family*	*New Genus*	*New Species*
Arthropoda	Corophiidae	*Corophium*	*spinicorne*	Arthropoda	Corophiidae	*Americorophium*	*spinicorne*
Arthropoda	Corophiidae	*Corophium*	*stimpsoni*	Arthropoda	Corophiidae	*Americorophium*	*stimpsoni*
Arthropoda	Corophiidae	*Corophium*	*acherusicum*	Arthropoda	Corophiidae	*Monocorophium*	*acherusicum*
Arthropoda	Corophiidae	*Corophium*	*insidiosum*	Arthropoda	Corophiidae	*Monocorophium*	*insidiosum*
Arthropoda	Corophiidae	*Corophium*	*oaklandense*	Arthropoda	Corophiidae	*Monocorophium*	*oaklandense*
Arthropoda	Corophiidae	*Corophium*	*japonica*	Arthropoda	Aoridae	*Grandidierella*	*japonica*
Arthropoda	Grapsidae	*Eriocheir*	*sinensis*	Arthropoda	Varunidae	*Eriocheir*	*sinensis*

Fall Dissolved Oxygen Levels in the Stockton Ship Channel

James Giulianotti and Stephen P. Hayes (DWR), jgiulian@water.ca.gov

Dissolved oxygen concentrations in the Stockton Ship Channel were monitored using the R/V San Carlos by staff of DWR's Bay-Delta Monitoring and Analysis Section from the late summer through the fall of 2002. Monitoring is conducted because dissolved oxygen levels can drop below 5.0 mg/L during this period each year, especially within the eastern portion of the channel. Low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand (BOD), reduced tidal influence, and intermittent reverse flow conditions in the San Joaquin River past Stockton are all thought to contribute to the dissolved oxygen decrease in this area.

These low dissolved oxygen levels can cause physiological stress to fish and inhibit upstream migration of salmon.

Monitoring for 2002 began in late July and was scheduled to continue through November. During each of seven scheduled monitoring runs, 14 sites are sampled from Prisoner's Point in the central Delta to the Stockton Turning Basin. Dissolved oxygen and water temperature data are collected for each site at the top and bottom of the water column during ebb slack tide using traditional discrete (Winkler titration) and continuous monitoring (Seabird 9/11multiparameter sensor) instrumentation[1].

Dissolved oxygen levels in the western channel (from Prisoner's Point to Disappointment Slough) were relatively high and stable from late July through September and ranged from 7.0 to 9.9 mg/L. During this same period, dissolved oxygen concentrations within the central channel (from Columbia Cut to Fourteen Mile Slough) were more variable, and ranged from 3.7 to 8.1 mg/L. In the heart of this region, surface and bottom levels dropped below 5.0 mg/L at Light 34 on August 20. In the eastern portion of the channel (from Buckley Cove to the eastern end of Rough and Ready Island), dissolved oxygen levels were more stratified, and a persistent dissolved oxygen sag (an area within the channel where dissolved oxygen levels were 5.0 mg/L or less) was present. The sag was present at the surface at Light 48 on July 23, and at the bottom from Light 40 to Light 43 on July 23. A minimum dissolved oxygen level of 3.3 mg/L was recorded at the bottom at Light 41 on September 5 when water temperatures were warm (22.3-24.7 ºC) and San Joaquin River inflows past Vernalis were low (approximately 1,002 cfs).

Monitoring in early October indicated that dissolved oxygen levels within the eastern channel improved to greater than 8.4 mg/L at the surface and greater than 7.4 mg/L at the bottom. This improvement could be due, in part, to cooler water temperatures (20.4-21.0 ºC), slightly improved San Joaquin River inflows (approximately 1214 cfs past Vernalis), and the presence of an algal bloom (organism identification pending) within this portion of the channel. Lower dissolved oxygen levels persisted within the central channel, however, as dissolved oxygen at the surface ranged from 4.7-7.0 mg/L and levels at the the bottom ranged from 4.6-7.2 mg/L. October dissolved oxygen levels in the western channel continued to be relatively high and stable and ranged from 7.7 to 8.2 mg/L.

1. Monitoring by vessel is supplemented by an automated multiparameter water quality recording station near Burns Cutoff at the western end of Rough and Ready Island.

San Francisco Bay Fisheries Monitoring

July-December 2002

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Summer and fall catches of several cold-temperate species, including Dungeness crab, Pacific herring, and English sole, confirmed the preliminary report of strong year classes in the previous IEP Newsletter (Summer 2002). Based on catch data, the 2002 Dungeness crab index will be the third highest for the period of record (1980-2002) and follows a high 2001 index. Two sequential years of high Dungeness crab indices strengthen the hypothesis that cool ocean temperatures result in strong year-classes in the San Francisco Bay.

The 2002 Pacific herring age-0 catch was the third highest since 1986; we have also observed three years of increasing Pacific herring age-0 catches from 2000-2002. Interestingly, the adult Pacific herring biomass, based on spawning and hydroacoustic surveys, has not been notably high the past three years. But historically, adult biomass and subsequent age-0 abundance has not been strongly correlated in the bay.

English sole age-0 catch was also very high in 2002, but about 1,000 less than the record high 2001 catch of 4,962 fish. The 2002 index will probably be very similar to the 2000 index, which was the second highest for the period of record; therefore, the three highest indices will be in the past three years.

Although our 2002 catch of the shokihaze goby (*Tridentiger barbatus*) decreased by almost ten times from 2001, it remained far more common in our collections than the other two species of *Tridentiger*, the chameleon goby (*T. trigonocephalus*) and the shimofuri goby (*T. bifasciatus*). Most shokihaze gobies were again collected in Suisun Bay and lower Sacramento River channel stations in fall.

In December we collected one new species for the study, a slipskin snailfish (*Liparis fucensis*). All the snailfish collected to date have been the showy snailfish, *L. pulchellus*. Most snailfish have been collected from our Alcatraz Island station, which has a rock and cobble substrate. Also of interest is the very large (1,193 mm total length) Pacific electric ray we collected in December from South Bay (Figure 1). Depending on the reference, this is a near record size fish. We have collected only 11 electric rays in 22 year of sampling, and most have been from South Bay.

Figure 1 Pacific electric ray (*Torpedo californica*) and Kent Hespeler, DFG vessel captain, on the R/V *Longfin*, December 2002.

North Bay Aqueduct and 20mm Surveys

Ryan Mayfield (DFG) and Michael Dege (DFG), rmayfield@delta.dfg.ca.gov

The North Bay Aqueduct (NBA) larval fish survey began on February 15 and finished on July 15, 2002. A total of 56,995 fish were collected over the five-month survey. The catch was dominated by longfin smelt (40.4%), prickly sculpin (25.6%), and striped bass (16.3%). Catch in past surveys has usually been dominated by prickly sculpin; however, the 2002 catch was dominated by longfin smelt (Table 1). Delta smelt catch for 2002 totaled 2,649, which is greater than all other years combined (1995-2001). During February over 100 yolk-sac larvae from this total were sampled from one 10-minute tow in Miner Slough, which was a good indication that spawning took place early in the year and very close to one of our sampling stations (724). Longfin smelt catch (22,596) increased by nearly an order of magnitude from last year and is also greater than all other years of this survey combined. Prickly sculpin and striped bass catches were relatively low compared to all years.

Table 1 Percent of total catch for select species from the North Bay Aqueduct Survey 1995-2002[a]

	Delta Smelt (%)	*Longfin Smelt (%)*	*Prickly Sculpin (%)*	*Striped Bass (%)*
1995	<0.1	0.1	**70.0**	7.1
1996	0.4	0.0	**57.0**	9.1
1997	1.0	1.3	**67.4**	12.6
1998	<0.1	0.0	**65.3**	4.4
1999	0.1	0.1	**83.7**	9.1
2000	0.6	<0.1	36.2	**55.7**
2001	1.3	5.4	**33.9**	27.5
2002	4.7	**40.4**	25.6	16.3

[a] Highest percentages for a particular year are in bold.

When the weighted average of delta smelt catch from Barker Slough is equal to or greater than 1.0, NBA pumping is restricted to a five-day running average of 65 cfs. Although there were record numbers of delta smelt this year, pumping restrictions for the North Bay Aqueduct Pumping Facility were triggered on only two different occasions (4/4 and 4/28). For online information about the NBA Survey, see http://www.delta.dfg.ca.gov/data/nba/2000.

The low occurrence of these restrictions is probably due to most (96.4%) of the delta smelt distribution being located in Miner Slough and the Sacramento deep water channel. Only a small portion (1.4%) of the delta smelt catch was in Lindsey and Barker Sloughs, which are located near the pumping facilities.

20-mm Survey

The 20-mm larval and juvenile fish survey began on March 18 and finished on June 29, 2002. Eight surveys running every other week were completed. Moderate catches of young-of-the-year delta smelt first appeared in the south and central Delta with smaller catches near the confluence and north Delta. Near the end of the survey the majority of the population was located downstream of the lower Sacramento River and confluence area. Although there were indications of an early spawn occurring in February (see North Bay Aqueduct Survey), the 20-mm survey did not sample larval delta smelt until the second survey, or first week of April. A strong catch of delta smelt never occurred in any one survey like it has in recent years. When compared to mean annual CPUEs of all other years, the 2002 mean annual CPUE is the lowest of all survey years (Figure 1). Moderate catches of longfin smelt persisted throughout the season. While this is typical of most years, an unusually small size (<10 mm) was being sampled well into June. This is uncommon to see longfin smelt of this size so late in the season, and is well under the 30-mm average at this time.

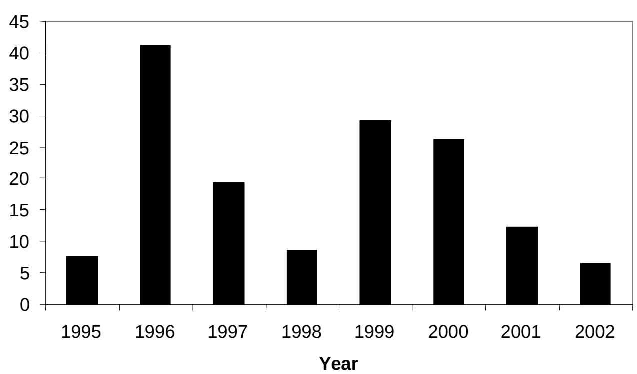

Figure 1 Annual mean density for delta smelt covering all years of the 20-mm survey

2002 was a dry year, which can typically cause the larval delta smelt distribution to shift landward toward the Delta, which can increase the likelihood of salvage at the state and federal pumping facilities. However, take levels at the SWP and CVP never reached a "red light" level of concern but a "yellow light" was reached from mid-May until mid-June. For online information about the 20-mm Survey, see http://www.delta.dfg.ca.gov/data/20mm/2000.

Mysids and Zooplankton

Lee Mecum (DFG), lmecum@delta.dfg.ca.gov

This summer net comparisons were conducted as part of a plan to extend monthly monitoring of mysids and zooplankton downstream into south and central San Francisco bays. To save time and money, it was proposed that the lower bay plankton surveys be included in the Bay Study's surveys. The initial intent was to compare mysid densities and size characteristics from samples collected by an experimental net selected to improve catch efficiency and shorten sampling time with those from the historically used *Neomysis* net so as to minimize interference with the Bay Study's sampling protocol. Since conducting the field work and analyzing the data, we have revised our thinking and plan to continue to use the *Neomysis* net at downstream locations.

On July 23, 2002, the historic *Neomysis* net and a net 1-meter in diameter were compared in Montezuma Slough at Hunter's Cut. The comparisons were made to determine whether a larger net fished for a shorter time would yield macro-zooplankton densities and size distributions comparable to the those captured in the *Neomysis* net. Twelve pairs of tows were made, starting with the 1-meter net (meter net) and alternating the nets. The meter net was lowered until the winch operator "felt" it hit the bottom, then slowly retrieved. Tow times for the meter net ranged from 2 to 4 minutes. The *Neomysis* net was towed using the historic protocol of 10-minute stepped oblique tows. The mysids in each sample were counted using the historic method. Mysids were measured from five randomly selected tow pairs. T-tests were used to compare the mysid densities estimated for each net and a tabled chi-square test was used to compare the length frequencies.

Two species of mysids were caught: *Acanthomysis bowmani* and *Neomysis kadiakensis*. The *Neomysis* net caught more *A. bowmani* than the meter net (mean densities 57.19 and 43.34, respectively) but less *N. kadiakensis* (mean densities 0.74 and 1.96 respectively). Paired t-tests indicated that the differences (P = 0.4181 for *A. bowmani* and 0.1187 for *N. kadiakensis*) were not statistically significant.

Length frequency distribution, however, was another matter. The meter net caught *A. bowmani* neonates more efficiently than did the *Neomysis* net but caught individuals > 5 mm in length less efficiently. Similarly, the meter net caught *N. kadiakensis* < 6 mm more efficiently, but those greater than or equal to 6 mm less efficiently. Tabled chi-square tests show the differences to be significant at the 0.001 level. No *Neomysis mercedis* were caught, so it is not possible to say how the two nets compare with respect to that species.

Since these tests were conducted it has been decided that there is insufficient time to conduct the zooplankton surveys simultaneously with the Bay Study survey and that the R/V *Longfin* cannot simultaneously accommodate the sampling gear for both surveys. Also, retrieving the meter net with its swinging weights in rough water could be unsafe. The *Neomysis* survey in the lower bay will be conducted on either the two days immediately preceding or the two days immediately following the Bay Study survey. To maximize continuity with the upper estuary data, the historic gear and protocol will be used. A larger portion of the pump sample will be retained to increase the resolution of the micro-zooplankton data. The San Pablo Bay stations to be sampled have not been determined.

Developing a Diagnostic Key for Identifying Larval Osmerids in the Sacramento-San Joaquin Delta

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We continued to analyze morphometric data for the Osmerid Key study. We focused our analyses on discriminating differences between osmerid larvae less than 16-mm standard length (SL) because these larvae present the most difficulty with consistent identification among researchers. Both live and preserved osmerid larvae (range 4-16 mm SL) from known-source cultures were selected for morphometric and meristic analysis. We used principal component analysis to examine relationships and variability of 18 length and 9 area morphometric parameters by fish length. Any missing data points were estimated using best-fit regression models and only those estimates that had an R-squared value of 90% or greater were included. The data was standardized by creating a ratio of each data point to the standard length.

We found the following significant results for each specific size range:

1. *Oil Globule and Yolk Sac:* is larger and retained longer in delta smelt larvae (7.0-10.0 mm); is smaller and absorbed at a shorter length (5.0-7.0 mm) in wakasagi larvae

2. *Air Bladder Development:* Develops earlier and at a shorter length in wakasagi (8.0-11.0 mm) compared to delta smelt (9.0-13.0 mm)

3. *Maximum Dorsal Finfold:* Wakasagi dorsal finfold tends to have a greater width compared to delta smelt at a similar size and age class.

4. *Maximum Finfold to Anal Opening:* The development and movement of the adipose fin toward the posterior is observed to be greater in the delta smelt larvae.

Based on preliminary data, our results indicate that morphometric characters can be used to discriminate larval delta smelt and wakasagi from one another. Further, our data suggests that multiple characteristics should be used in identification whenever possible, along with visual characters (e.g., body pigmentation). Our future plans include having blind QA/QC tests by trained and untrained personnel to determine which identified characters are consistently useful for discriminating the two osmerid species. Ultimately, our aim is to combine information learned from this study with detailed drawings of larvae to develop a pictorial key available for public distribution.

CONTRIBUTED PAPERS

Predicting Juvenile Chinook Emigration Using Environmental Parameters

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Salmon biologists from fish resource management agencies (MAs) are working on determining the optimal time to close the Delta Cross Channel gates (DCC) to maximize the protection for juvenile Chinook salmon as they emigrate down the Sacramento River from October through January. The 1995 Water Quality Control Plan allows 45 days of DCC gate closure from November 1 through January 31 for fish protection. After January 31 the DCC gates are closed until mid-May under the Winter Run Protection Plan. Since the California Environmental Water Account (EWA) and Central Valley Project Improvement Act "B2" Account are limited water resources, we cannot afford to take actions that would protect the entire population. We are continually analyzing existing data and incorporating new data to improve the decision process in an effort to protect the majority of emigrating juvenile Chinook salmon.

Currently we have at least seven consecutive years (1995-2002) of monitoring data from the Knights Landing rotary screw trap, the Sacramento River Midwater and Kodiak trawl at Sherwood Harbor, and Sacramento River area beach seine. Recent monitoring data (1998–2002) from the rotary screw traps in Mill, Deer, and Butte creeks were analyzed to help determine migration rates between the upper tributaries and the lower Sacramento River. We re-analyzed changes in environmental parameters such as flow, water temperature, precipitation, and turbidity prior to the peak juvenile Chinook salmon migration past each monitoring station. Our focus was on changes that occurred two to five days prior to the peak migration to allow fish resource MAs enough time to make a decision to close the DCC gates and the water project agencies to implement the recommendation.

As individual salmon runs were added to the list of threatened, endangered, or species of concern, it became less important to distinguish them in Sacramento River and Delta monitoring samples because the distinction had little bearing on decisions to implement protective actions. To simplify data reporting, the EWA biologists adopted the term "older juveniles" to describe juvenile salmon from the winter (endangered), spring (threatened) and late-fall (federal candidate) runs that migrate to the Delta in the fall and winter months. Some juveniles from all three runs migrate downstream during this time and are not distinguishable based on their size. They arrive in the Delta concurrently and their presence can instigate protective actions, regardless of the proportion of each run in the mix. We distinguish "older juveniles" using the minimum winter-run length criteria at Knights Landing and in the Sacramento River trawl and beach seines (White and others 2002).

Upper Tributaries

Sufficient data were not available for this type of analysis prior to 1998-1999 for Deer Creek and 1999-2000 for Mill and Butte Creeks. From our analysis we did not find changes in flow, water temperature, precipitation, or turbidity that consistently preceded the emigration out of Mill or Butte creeks. We will continue to analyze these stations, as more data become available.

A daily change in flow greater than 35 cfs indicated the start of the migration out of Deer Creek. Emigration from Deer Creek preceded the peak in emigration at Knights Landing, Sacramento River trawl, and the Sacramento area beach seines anywhere from five days to three months for water years 1999 through 2002 (Figures 1A-1G).

We found that flow in the upper tributaries influenced the length of the migration period to the lower Sacramento River. Increases in November flows shorten the length of the migration between the upper tributaries and the lower Sacramento River. For waters years 2000 through 2002 the start of the emigration out of Deer, Mill, and Butte creeks occurred in October and by early November for Deer Creek in 1999 (Figures 1A-1G). The average flow in the upper tributaries between August and October was the highest in 1999 and the lowest in 2002. The shortest period of migration between the upper tributaries and the lower Sacramento River monitoring stations was in 1999, as expected due to the flows, but the second shortest was in 2002, the driest year (Figures 1A-1G). We found that in both 1999 and 2002 the average flow in November increased between 100 cfs and 180 cfs for the three tributaries compared to the August-October period. In 2000 it only increased between 25 cfs and 75 cfs and in 2002 there was no change in the average flow.

Knights Landing

At Knights Landing, a combination of flow, temperature, and catch criteria best predicted the start of the peak migration. There were usually a few emigrating Chinook salmon throughout the summer, but the peak migration started between October 10 and November 15 from 1996 through 2002 (Figures 2A - 2G). At that time of year, precipitation usually causes Wilkins Slough flow to increase sharply; flows between 7,000 cfs and 10,000 cfs were associated with the start of the peak migration. We found that a flow of 7,500 cfs provided us with a four to six day lead-time before the peak migration started. However, on some occasions, flows near 7,500 cfs occurred in September and October from reservoir releases not precipitation (White and others 2002). Those reservoir-induced flows did not stimulate emigration. This is where the temperature criterion was helpful.

The water temperature at Knights Landing was seasonally consistent with changes in air temperature. Similar to flow, the start of peak salmon emigration was related to a range of temperatures from 12° C to 13.25° C. At Knights Landing, the seasonal temperature trend was more consistent than flow, therefore a temperature criterion of 13.5° C excluded early season flows near 7,500 cfs from our criteria to close the DCC.

The temperature and flow criteria work in series. When the water temperature decreases below 13.5° the next flow increase to 7,500 cfs indicated that the start of peak migration would occur within the next four to six days (Figures 2A - 2G). A catch criterion was then added to help narrow the time frame by several days. We found that a catch index of three “older juveniles” indicated the start of the peak migration in all years (Figures 2A - 2G). The catch index is the daily catch standardized to a one-trapday. This criteria, combining temperature, flow, and catch, allows us enough time to make and implement a decision to close the DCC at the beginning of the emigration (White and others 2002).

Sacramento River

In the Sacramento area, as part of the IEP Delta Juvenile Fish Abundance and Distribution Monitoring Program, the USFWS operates two kinds of gear, the beach seine and trawl. USFWS operated the trawl every other day, and the beach seines on the intervening days. By alternating, we had coverage every weekday even though the gears target different Chinook life stages. The USFWS sampling targets younger, possibly rearing Chinook salmon with the beach seines and older, possibly actively migrating Chinook salmon with the trawl. In this analysis we assumed that there was no gear avoidance due to water clarity. However, gear avoidance could be a factor when water clarity is high and would affect this analysis. The EWA salmon biologists are looking into gear avoidance issues and plan to incorporate any new data into the decision process.

Criteria that incorporated the change in flow, turbidity, and catch worked best in predicting the start of the peak migration for both the trawl and the beach seine. This enables us to use either gear when deciding to close the DCC. Similar to Knights Landing, a few Chinook were recovered throughout the summer, but the peak migration started for both gear types between November 12 and December 21 from 1996 through 2002, except in the trawl for 1999-2000 and in both gear types for 2000-2001 (Figures 3A - 3G). In 1999-2000 the peak migration in the trawl started January 13. In 2000-2001 the peak migration began in mid-January for both gear types (Figures 3A - 3G). In all years, except 1999-2000, the criteria for both gear types were met within three days of each other (Figures 3A - 3G).

Between November and December the flows are increasing gradually but can also increase rapidly with large precipitation events. A three-day change in flow between 600 cfs and 3,000 cfs for four consecutive days preceded the start of the peak migration anywhere from two days to two weeks, except in 2000-2001 (Figures 3A - 3G). Therefore the flow criterion was too variable to use independently — especially considering the limited EWA resources — and adding turbidity tightened up the criteria.

Changes in water clarity also preceded the peak migration and were closely associated with the flow criterion. Once the flow criterion was met, a secchi reading less than 0.75 meters narrowed the time frame prior to the start of the peak migration. The secchi criterion preceded the peak migration anywhere from two days to a week except in the trawl for 1999-2000 and in both gear types in 2000-2001 (Figures 3A - 3G). In those two years the period between October and January was drier with no large flow events. Under these conditions we found that the flow and turbidity criteria were met several times and that some “older juveniles” were recovered within a week but the catch was scattered and in low numbers. We determined that a catch index criterion of three “older juvenile” Chinook helped predict the start of the peak migration in all years (Figures 3A - 3G). The catch index is the daily catch standardized to ten tows per day for the trawl and standardized to eight hauls per day for the beach seine.

Again, similar to Knights Landing, the advantage of having the flow, turbidity, and catch criteria is that they provide a way to predict the start of the peak emigration a few days in advance. Even though the criteria are specific for both Knights Landing and the Sacramento trawl and beach seine, both sets of criteria were met within a week of each other in all years (Figures 1A - 1G). This indicates that these criteria will help us improve our decision-making process and increase the protection of juvenile Chinook salmon migration near the DCC.

Acknowledgments:

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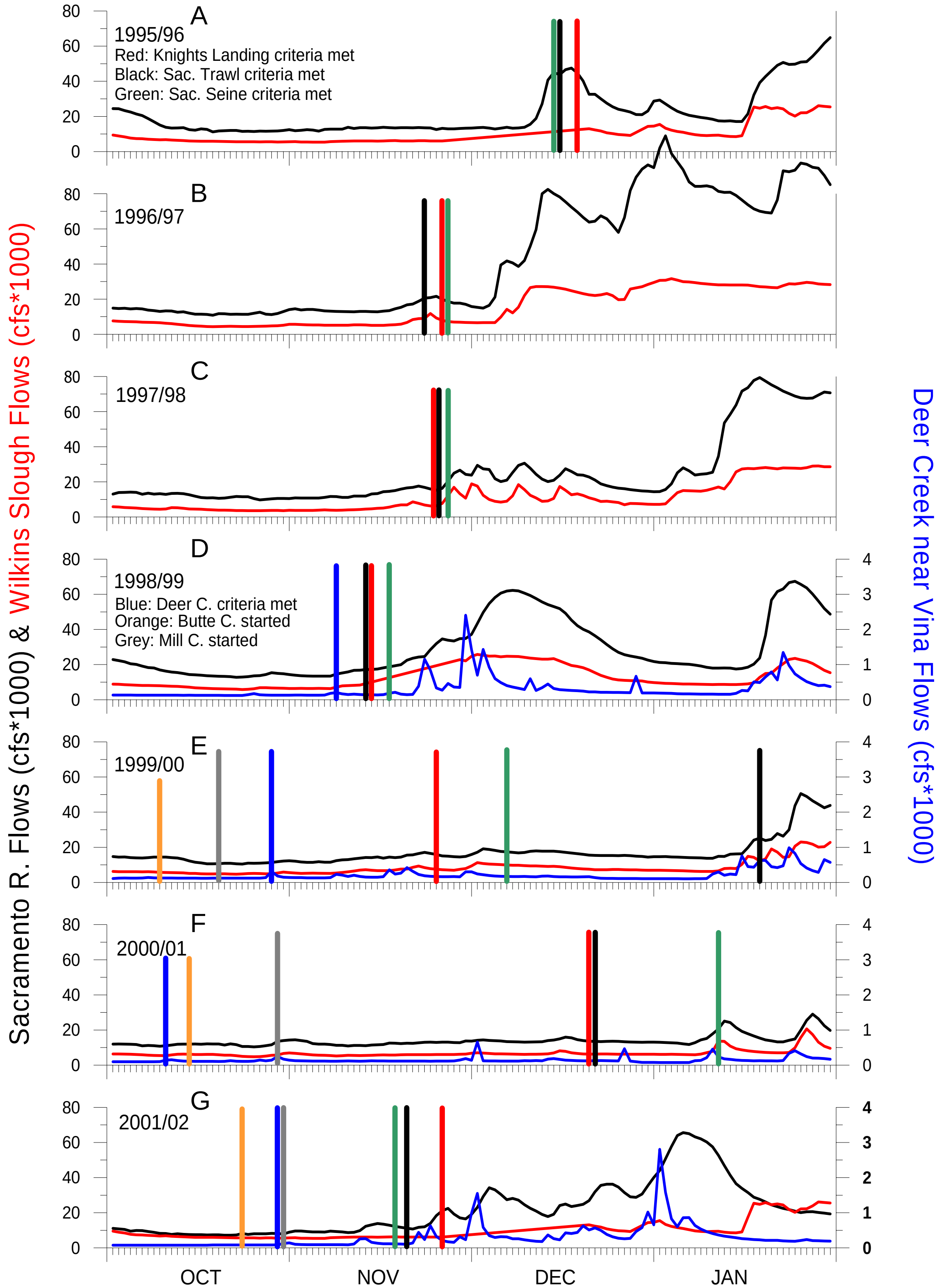

Figure 1A-1G Timing of "older juvenile" Chinook emigration between October and January for water years 1996 through 2002

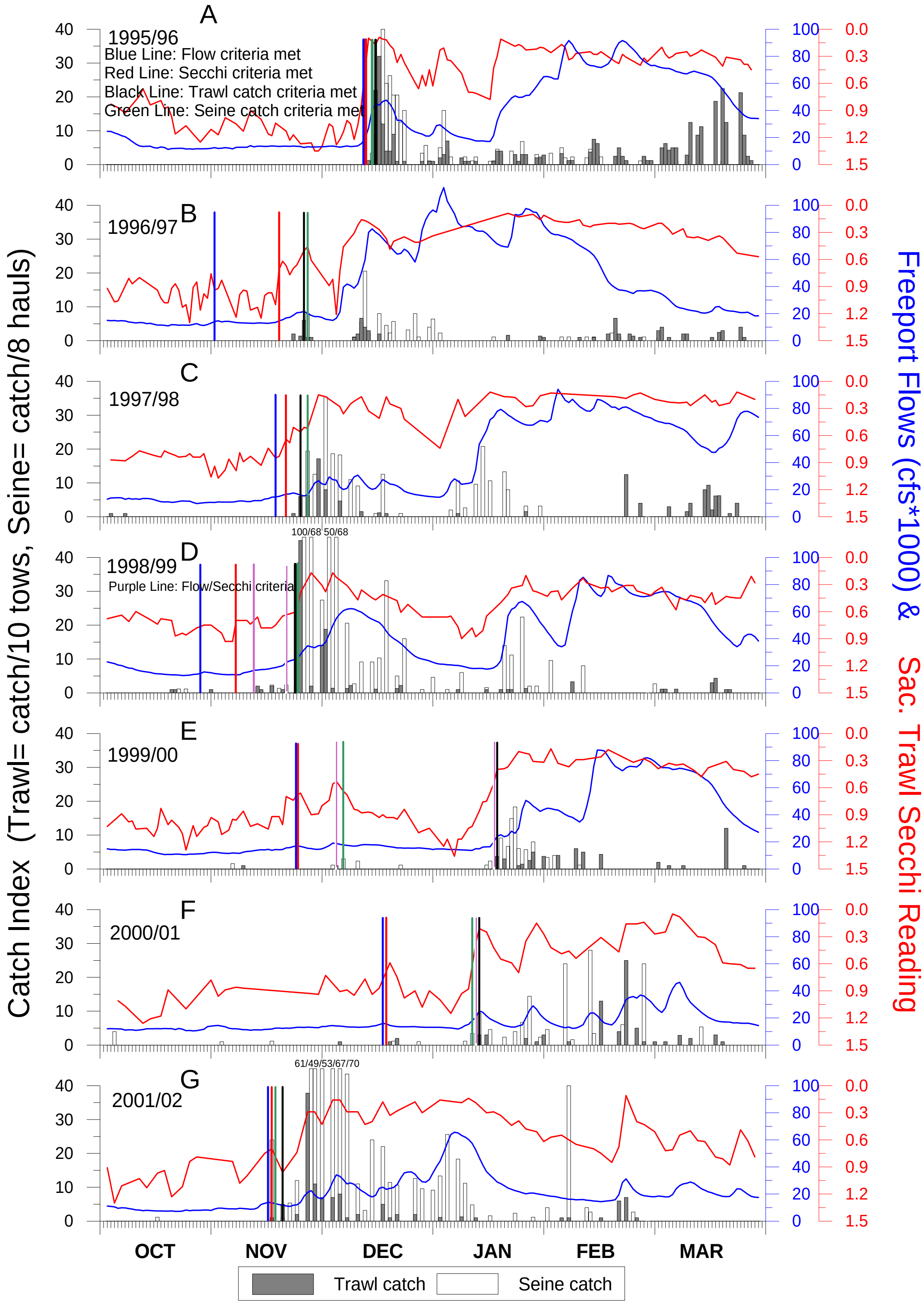

Figure 2A-2G Number of "older juvenile" Chinook recovered in the Knights Landing rotary screw traps between October and March for water years 1996 through 2002

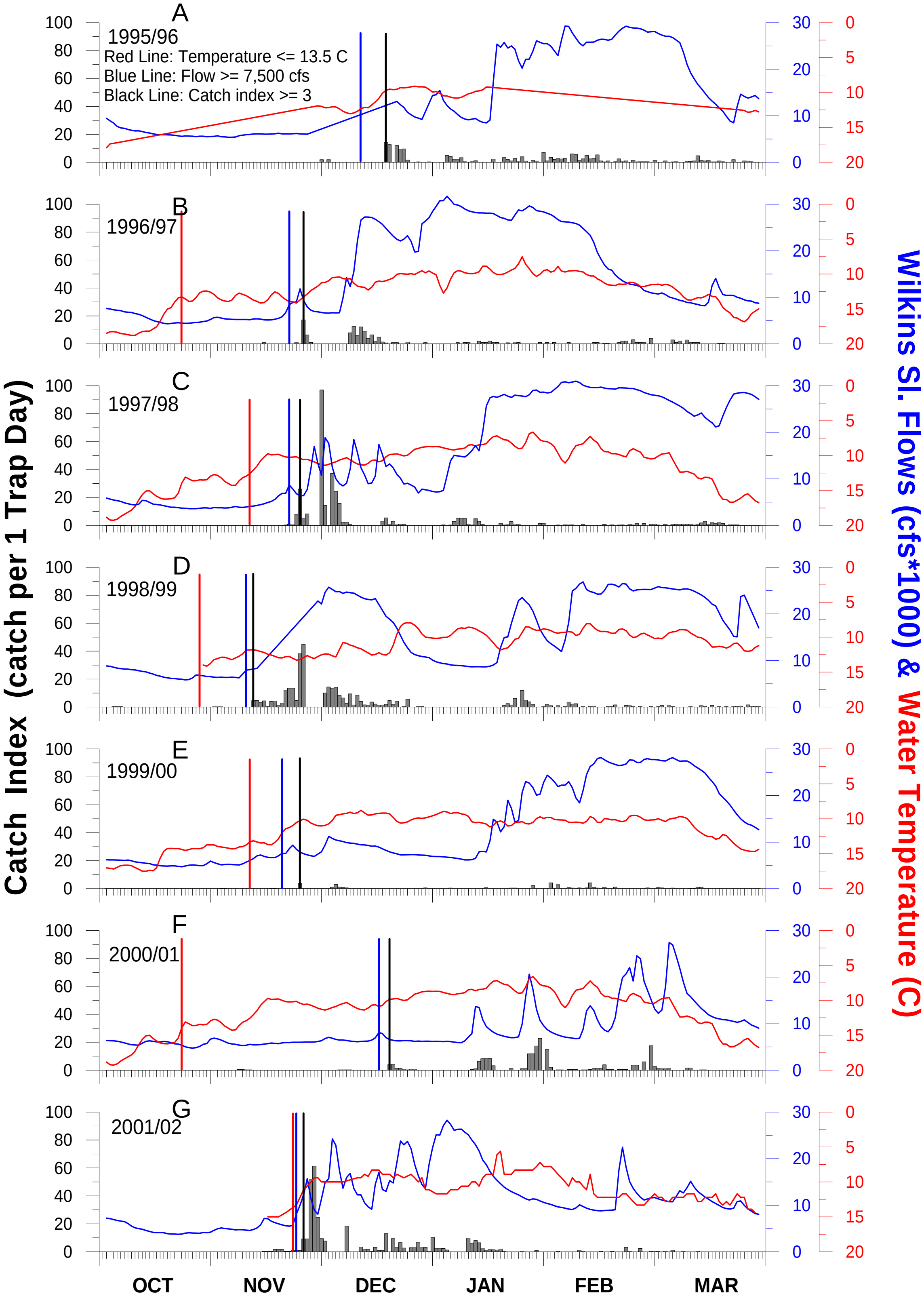

Figure 3A-3G Number of "older juvenile" Chinook recovered in the Sacramento River Area trawl and beach seine between October and March for water years 1996 through 2002

Microcystis Blooms in the Delta

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Blooms of the bluegreen algae *Microcystis aeruginosa* (Microcystis) have occurred in the Delta from July through November since 1999 (Figure 1). In 2002, these blooms occurred in the southern regions of the Delta in Middle and Old rivers and the lower San Joaquin River westward to Antioch.

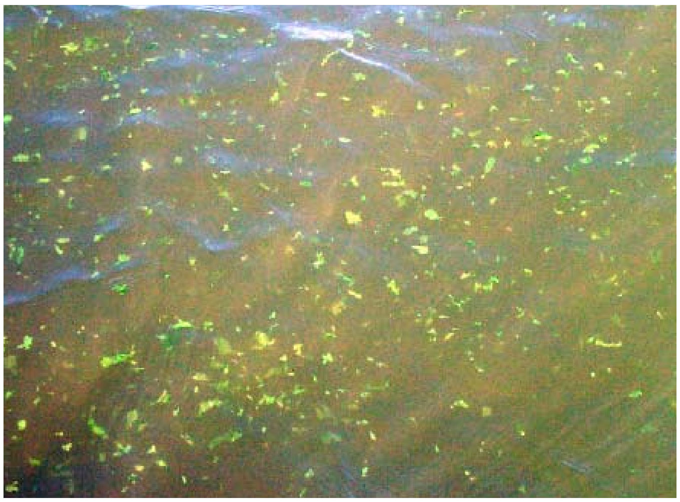

Figure 1 ***Microcystis aeruginosa*** **bloom in the Delta, 2002**

Microcystis is a common bluegreen alga in freshwater and brackish water ecosystems, including the Delta. However, *Microcystis* blooms are uncommon and have not been encountered in the Delta in recent history. These blooms occur on the surface of the water where the cells aggregate into colonies that look like little flakes of lettuce (Figure 2) or, in very large blooms, like green paint spread on the water.

Microcystis blooms can be toxic. Some *Microcystis* produce a potent toxin called microcystin that is released into the water when the cells die and decompose. This toxin is odorless and resistant to degradation and can make its way into the food chain. Microcystins produce both acute and chronic toxicity. Ingestion of small quantities of *Microcystis* by humans causes flu-like symptoms such as nausea, vomiting, or cramps. Long-term exposure is associated with liver dysfunction, including malignancy. Domestic animals and wildlife, including fish, are also susceptible to the adverse effects of this toxin. The LD 50 is between 50 and 300 µg/kg bodyweight in mice and rats and the lethal oral dose is about 100 times higher. Chronic toxicity may occur at lower doses (CAHFS 2000).

The United States does not have a drinking water standard for total microcystin, but Canada, Australia, and Great Britain use a guideline of 1 µg/L (OPHS 2002). Total microcystin concentration exceeded this standard at Mound Slough near Franks Tract in 2000 when the two microcystins type LR and RR totaled 1.8 µg/L. No toxicity was found in water samples collected at eleven other stations during this single sampling event in 2000.

The full geographic extent, density and toxicity of the *Microcystis* blooms in the Delta are not known. The current DWR Environmental Monitoring Program detects the bloom but does not quantitatively sample the density or biomass of this bloom because the bloom occurs on the surface and the routine water sampling is at 1-m depth. The observed geographical extent of the bloom is also poorly described because of the limited number of sampling stations in the monitoring program.

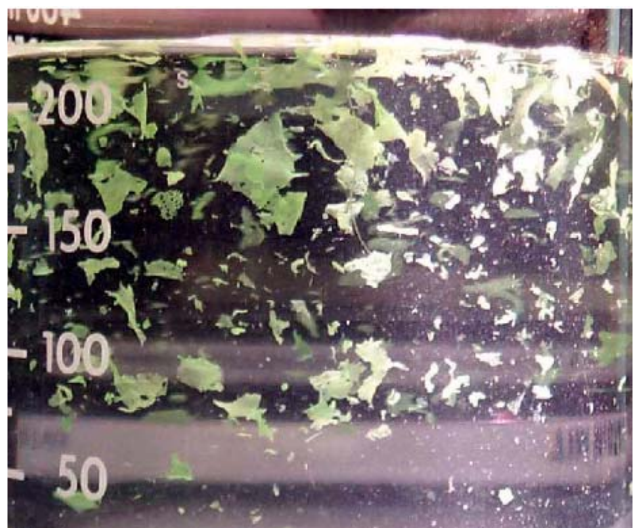

Figure 2 Close-up of *Microcystis aeruginosa* colonies.

A proposal is currently in review by the Interagency Ecological Program to develop a sampling protocol, compile a literature database for human health and ecosystem effects, and to monitor the geographic extent and toxicity throughout the bloom period. Although these *Microcystis* blooms are a potentially serious health and ecosystem threat, extensive study is needed to fully assess that potential.

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Baby Steps Toward a Conceptual Model of Predation in the Delta: Preliminary Results from the Shallow Water Habitat Predator-Prey Dynamics Study

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Study Background

The Shallow Water Habitat Predator-Prey Dynamics Study is an ongoing IEP study designed to update and expand our understanding of piscivore-prey interactions in the Delta. Field work for this project occurred in 2000-2001 and is scheduled to continue in 2003. This article provides preliminary data on the feeding ecology and habitat use of striped bass and largemouth bass. A subsequent newsletter article currently in preparation will provide further details on the sampling opportunities and limitations that guided the analyses we present here.

Scope

Any study of piscivory in shallow water habitats (SWHs) needs to include definitions of (1) which habitats were considered "shallow", and (2) which fishes were considered piscivorous (Sheaves 2001). We sampled near shore within river channels and flooded islands (Table 1) in water less than 4 m deep. Therefore, we define SWH as less than 4 m deep. As described below, this definition is based on our gear choices rather than any ecological phenomena.

Table 1 Shallow Water Habitat Predator-Prey Dynamics Study sample sites

Site name	*Habitat type*	*Region*
Liberty Island	flooded island	Yolo Bypass
Decker Island	river channel edge	Lower Sacramento
Sherman Island	river channel edge	Lower Sacramento
Medford Island	river channel edge	Central Delta
Mildred Island	flooded island	Central Delta

Most fish species will opportunistically prey on smaller fishes (Johnson and Ringler 1998). Since the IEP primarily monitors the distribution and abundance of juvenile and small adult fishes, we were interested in focusing our data collection efforts on species that commonly prey on juvenile and small adult fishes. Moyle (2002) identifies 20 extant species that occur in the Delta and at least occasionally eat juvenile and small adult fishes (Table 2). During our 2000-2001 sampling, striped bass and largemouth bass accounted for 88% of the individuals of these 20 species. Each of the remaining 18 species accounted for at most 4% of individuals collected. In addition to being the most abundant, striped bass and largemouth bass also were on average the most frequently piscivorous (Table 1). Based on these observations, we limited our analyses to striped bass and largemouth bass. In this excerpt, we provide preliminary answers to the following questions, which provide the basis for developing a conceptual model of predation in Delta SWHs:

- What are the diet compositions of striped bass and largemouth bass?
- Do striped bass and largemouth bass switch prey based on changes in abundance?
- Which Delta SWHs are used by striped bass and largemouth bass, and what are some important characteristics of these habitats?
- In 2001, did estimated fish consumption by striped bass and largemouth bass inhabiting SWH vary over space and time, and if so, why?

Table 2 Known and potentially piscivorous fishes reported to occur in the Sacramento-San Joaquin Delta (Moyle 2002), their combined seine and gillnet relative abundance and size distribution from this study, and where applicable, the frequency of occurrence of fish prey among all stomachs examined.

Common name	*Scientific name*	*Status*	*Abundance*	*% of total abundance*	*mean FL (range)*	*FOfish*
Striped bass	*Morone saxatilis*	nonnative	7,482	76	181 (53-776)	0.25
Largemouth bass	*Micropterus salmoides*	nonnative	1,170	12	142 (51-458)	0.33
White catfish	*Ameiurus catus*	nonnative	379	4	250 (62-373)	0.05
Sacramento pikeminnow	*Ptychocheilus grandis*	native	370	4	179 (72-512)	0.17
Chinook salmon	*Oncorhyncus tschwaytsha*	native	247	3	NA	NA
Channel catfish	*Ictalurus punctatus*	nonnative	96	1	318 (61-582)	0.03
Black crappie	*Pomoxis nigromaculatus*	nonnative	50	1	124 (52-309)	0.20
Pacific staghorn sculpin	*Leptocottus armatus*	native	10	0	NA	NA
Brown bullhead	*Ameiurus nebulosus*	nonnative	7	0	NA	NA
Warmouth	*Lepomis gulosus*	nonnative	7	0	NA	NA
Spotted bass	*Micropterus punctulatus*	nonnative	5	0	NA	NA
White sturgeon	*Acipenser transmontanus*	native	1	0	NA	NA
Black bullhead	*Ameiurus melas*	nonnative	1	0	NA	NA
Green sturgeon	*Acipenser medirostrus*	native	0	0	NA	NA
Rainbow trout	*Oncorhyncus mykiss*	native	0	0	NA	NA
Blue catfish	*Ictalurus furcatus*	nonnative	0	0	NA	NA
Green sunfish	*Lepomis cyanellus*	nonnative	0	0	NA	NA
Smallmouth bass	*Micropterus dolomeiu*	nonnative	0	0	NA	NA
White crappie	*Pomoxis annularis*	nonnative	0	0	NA	NA
Brown trout	*Salmo trutta*	nonnative	0	0	NA	NA

Methods

During August-October 2000 and in March 2001, we sampled fishes once per month at three sites. During April-October 2001 we sampled once per month at five sites. These sites were described in detail by Nobriga and others (2001) and were grouped into three regions for most data analyses (Table 1). For all results reported in this paper, fishes were collected using seines (30 m x 1.8 m; 3.2 mm mesh) and experimental gillnets (60 m x 2.4 m with randomized graded-mesh panels of 51 mm to 102 mm stretch mesh). Seines typically sampled water about 1 m deep, whereas gillnets were fished adjacent to the seine sites in water 2 to 4 m deep. Piscivorous fishes or their stomachs were preserved in 10% to 15% formalin. Stomach contents were enumerated and identified to lowest possible taxon (fish) or lowest practicable taxon (invertebrates).

Fish habitat associations were examined by testing for a significant effect of Delta region on natural log-transformed striped bass and largemouth bass CPUE (number per 10,000 m^3 seined or number per hour of gillnetting). Assignments to age classes (year of birth) were based on length-frequency plots. Choices regarding which data were appropriate for statistical analysis were based on assessments of gear efficiency that will be described in a subsequent newsletter article. Regional differences in physical habitat were examined qualitatively by comparing mean Secchi disk depth (m, ± SE) to the mean volume (number of 19-liter buckets, ± SE) of submerged aquatic vegetation (SAV) collected per seine haul.

Bioenergetic consumption indices were used to examine if and how relative predation pressure varied spatially and temporally in the Delta during 2001. We used existing validated bioenergetics models for striped bass and largemouth bass (Hanson and others 1997) and data collected during this study (Table 3) to develop indices of fish consumption by individuals for the age-0 and age-1 cohorts larger than 80 mm FL. Input data for the fish consumption indices were pooled by region (Table 2) for each of six time periods of approximately equal length (26-27 days) from our April-September 2001 sampling season. The indices were calculated as follows:

$$C_F = C_{\text{age-1SB}}(FO_{\text{fish}}) + C_{\text{age-1LB}}(i_{\text{fish}}) + C_{\text{age-0SB}}(FO_{\text{fish}}) + C_{\text{age-0LB}}(FO_{\text{fish}})$$

Where C_F = fish consumption, and the other C terms with subscripts represent the contribution to total consumption by an individual age-1 striped bass, age-1 largemouth bass, age-0 striped bass, and age-0 largemouth bass respectively. The FO_{fish} terms (frequency of occurrence) scale total consumption to fish consumption and represent location, (and whenever possible, month of collection), specific *FO* of prey fish in stomachs containing food for age-1 striped bass, age-1 largemouth bass, age-0 striped bass, and age-0 largemouth bass respectively. In some cases diet data were pooled across adjacent months to increase the sample size on which the FO_{fish} terms were based. The consumption estimates for each species-age class were then multiplied by a number of individuals based on seine CPUE (using an arbitrary maximum of 10,000 fish) to derive consumption indices (Table 3). Age-1 predator abundances were held constant throughout the simulation and age-0 predator abundances were held constant once they entered the simulation (July). To remove minor consumption differences due to modeling 26-day and 27-day time periods, we reported the bioenergetic indices as mean daily values.

Table 3 Bioenergetic model components and the source data used to derive consumption indices

Input parameter	*Data source*
Predator growth rate	apparent growth for each modeled time period using mean fork length (mm) vs. date converted to mean weight (g) vs. date
Predator abundance	age- and species-specific CPUE scaled to a maximum value of 10,000 fish
Water temperature	interpolations between monthly mean temperature (degrees Celsius) in each region
Prey energy density	held constant at 4,429 J/g (equal to amphipod estimate in Hanson and others 1997)

Assuming our fish consumption indices were reasonable, we expected the indices to be a positive function of a metric of prey fish availability. To test this hypothesis, we used linear regression to examine the relationship between the fish consumption indices and the mean number of fish collected per seine haul in the same month and region. Because the abundance of striped bass and largemouth bass affected the fish consumption estimates, striped bass and largemouth bass were omitted from the calculations of number of fish per seine haul.

Results

Both striped bass and largemouth bass ate numerous invertebrate and vertebrate prey types, but few occurred in more than 10% of the stomachs examined (Table 4). Gammarid amphipods, yellowfin gobies, and unidentified fishes had at least 10% FO in the diets of both predators. Striped bass also commonly ate mysids and *Corophium*. Mysids and *Corophium* were not commonly eaten by largemouth bass, which instead had at least 10% FO of two insect groups (midges and damselflies) not commonly eaten by striped bass.

The prey fishes eaten by striped bass and largemouth bass varied through time (Table 5). Though FO differed, the dominant prey fishes of both predators during summer 2000 were yellowfin goby and inland silverside. A lamprey ammocoete was the only native fish found in a predator stomach during that period. The following spring (March-June 2001), both species' diets included several native species, and striped bass had considerably lower FO of yellowfin goby. By summer 2001 native fish species were again virtually absent from stomach contents. Although the largemouth bass diet in summer 2001 was similar to summer 2000, striped bass continued to show lower FO of yellowfin goby than in 2000, taking much greater proportions of threadfin shad and inland silverside.

Table 4 Diet composition of striped bass and largemouth bass for 2000-2001. Data are raw frequencies of occurrence. Frequencies add to > 100 because there was often more than one prey type in a given stomach

			striped bass	*largemouth bass*
number of stomachs examined			519	234
number of stomachs containing food			292	180
General Prey Types	*Common names*	*Scientific names*		
Plant material	filamentous algae	*Melosira* spp.?		0.6
	other plant material	various		0.6
Crustaceans	copepods	various	2.1	2.8
	cladocerans	various	0.3	5.6
	Corophium	*Corophium* spp.	23	9.4
	gammarid amphipods	Gammaridae	14	33
	oppossum shrimp	Mysidacea	35	1.7
	isopods	Isopoda	2.4	1.7
	Siberian prawn	*Exopalaemon modestus*	2.4	2.2
	Bay shrimp	*Crangon* spp.	2.4	0.6
	mitten crab	*Eriocheir sinensis*	0.7	
	crayfish	*Pascifasticus lenuisculus*	0.3	2.2
Insects	midges	Chironomidae	3.1	13
	black flies	Simuliidae	0.3	
	damselflies	Zygoptera	2.1	28
	dragonflies	Anisoptera		1.1
	true bugs	Heteroptera		5.6
	ants	Formicidae	0.3	
	other insects	various	0.3	3.9
Mollusks	clams	unspecified	1	
Annelids	polychaetes	unspecified	0.3	
	oligochaetes	unspecified	0.3	
Fishes	fish eggs	unspecified		0.6
	lamprey ammocoete	*Lampetra* spp.	0.3	
	American shad	*Alosa sapidissima*		0.6
	threadfin shad	*Dorosoma petenense*	6.5	2.8
	unspecified shad	Clupeidae	3.1	0.6
	chinook salmon	*Oncorhyncus tshawytscha*	0.3	0.6
	catfishes	Ictaluridae		1.7
	splittail	*Pogonichthys macrolepidotus*	0.3	
	golden shiner	*Notemigonus crysoleucas*		0.6
	killifish/mosquitofish	Cyprinodontiformes	0.7	2.2
	inland silverside	*Menidia beryllina*	7.2	7.2
	prickly sculpin	*Cottus asper*	0.3	4.4
	striped bass	*Morone saxatilis*	2.1	1.1
	largemouth bass	*Micropterus salmoides*	0.7	2.2
	sunfishes	*Lepomis* spp.	0.3	0.6
	tule perch	*Hysterocarpus traski*		1.1
	yellowfin goby	*Acanthogobius flavimanus*	15	13
	shimofuri goby	*Tridentiger bifasciatus*		0.6
	shokihaze goby	*Tridentiger barbatus*	0.7	
	unidentifiable fishes	various	19	19
Other vertebrates	mice	Musculidae		0.6
	bullfrog tadpole	*Rana catesbiana*		0.6

Multiple age classes of striped bass and largemouth bass were collected from SWH (Table 6). The three age classes of largemouth bass collected exhibited similar regional distributions, whereas the distributions of striped bass age classes differed from one another. Seine CPUE of age-0 through age-2+ largemouth bass age classes were significantly higher in the central Delta than the other regions. Although we did not detect significant differences in largemouth bass CPUE between the lower Sacramento and Yolo Bypass regions, no largemouth bass were collected from the Yolo Bypass site, whereas largemouth bass were collected in small numbers at both sites that comprised the lower Sacramento River region. In contrast to largemouth bass, higher mean striped bass CPUEs were observed in the lower Sacramento River and Yolo Bypass than in the central Delta. This pattern was significant for age-1 striped bass ($P = 0.02$, Table 6), but was not significant for age-0 striped bass ($P = 0.06$, Table 6). The CPUE of age-1 and older striped bass collected in gillnets did not differ between the lower Sacramento and central Delta regions ($|t| = 0.607$; $P = 0.55$). A *t*-test was used for the gillnet data because no gillnetting occurred in the Yolo Bypass region.

Table 5 Raw frequencies of occurrence of prey fishes in the stomachs of striped bass and largemouth bass over three seasons

	Striped bass			*Largemouth bass*		
n =	*89*	*81*	*116*	*54*	*63*	*49*
Prey fish taxa	*Jul-Oct 2000*	*Mar-Jun 2001*	*Jul-Oct 2001*	*Jul-Oct 2000*	*Mar-Jun 2001*	*Jul-Oct 2001*
Native species						
chinook salmon	0	1	0	0	1	0
prickly sculpin	0	1	0	0	7	1
splittail	0	1	0	0	0	0
tule perch	0	0	0	0	2	0
lamprey	1	0	0	0	0	0
Nonnative species						
striped bass	1	2	3	0	2	0
largemouth bass	1	0	1	1	2	1
sunfishes	1	0	0	1	0	0
threadfin shad	1	3	15	0	0	5
American shad	0	0	0	0	0	1
unspecified shad	3	0	6	0	0	1
yellowfin goby	28	7	7	5	6	11
shimofuri goby	0	0	0	0	0	1
shokihaze goby	0	0	2	0	0	0
cyprinodontiforms	0	1	1	1	2	0
inland silverside	5	2	14	4	3	6
golden shiner	0	0	0	0	0	1
catfishes	0	0	0	1	2	0

Table 6 Results of ANOVAs and Tukey multiple comparison tests for unequal sample size for the effect of region on the seine CPUE of striped bass and largemouth bass. The number of each species-age class modeled in the fish consumption indices also is included.

age class and species	*time period tested*[a]	*F statistic*	*P-value*	*Multiple comparison*	*cenDel CPUE*	*cenDel modeled*	*lowSac CPUE*	*lowSac modeled*	*yolByp CPUE*	*yolByp modeled*
age-0 largemouth bass	Jul-Oct	4.55	0.03	cenDel > (lowSac = yolByp)	7.157	1,517	0.0945	0[d]	0	0
age-1 largemouth bass	Mar-Oct	17.9	$5 X 10^{-6}$	cenDel > (lowSac = yolByp)	6.557	1,389	0.5204	110	0	0
age-2 largemouth bass[b]	Mar-Oct	17.4	$6 X 10^{-6}$	cenDel > (lowSac = yolByp)	0.8723	NA	0.0526	NA	0	NA
age-0 striped bass	Jul-Oct	3.45	0.06		9.900	2,098	46.44	10,000	48.68	10,000
age-1 striped bass	Mar-Jul	4.65	0.02	cenDel < (lowSac = yolByp)[c]	0.5784	123	2.714	679	5.652	679

[a] based on data that will be presented in a subsequent newsletter article

[b] not used in bioenergetics simulation

[c] alpha = 0.05046

[d] not collected in low Sac until October

The major habitat differences we observed between the central Delta sites and the sites and those in either the lower Sacramento or Yolo Bypass regions were water clarity and SAV abundance (Figure 1). Mean Secchi disk depths at the central Delta sites were greater than 0.5 m, whereas mean Secchi disk depths on the Sacramento River side of the Delta were all less than 0.5 m. Water clarity also was positively correlated with the mean abundance of SAV per seine haul during 2001. Mean SAV abundance ranged from zero at Liberty Island to about 1.5 buckets per haul at the central Delta sites.

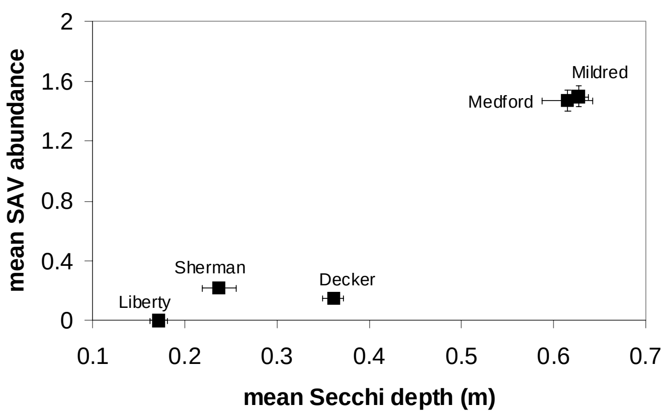

Figure 1 Bivariate plots of means and standard errors for Secchi disk depth (m) versus abundance of submerged aquatic vegetation retained in the seines for each of the five study sites sampled during 2001

As we hypothesized, our indices of fish consumption were correlated with observed fish abundance (Figure 2). Although it is intuitive that young predators eat more prey fish when more prey fish are available, this relationship is important because it suggests our fish consumption indices provided a realistic assessment of relative predation pressure over space and time.

Preliminary Synthesis

Generally, shallow water habitats have been considered refuges from predation. Sheaves (2001) questioned this hypothesis, arguing there is little empirical evidence that low abundance of large piscivores necessarily implies low levels of predation. In the Delta, age-0 and age-1 striped bass and largemouth bass are numerically dominant and, because they are highly piscivorous, are the best "barometers" of predation trends in SWH (Table 1).

Predator Diets Have Changed Substantially Since the 1960s

Striped bass and largemouth bass diet compositions are diverse (Table 4), and importantly, the prey fish composition we observed in 2000-2001 was very different from that reported during the last Delta-wide assessments of predator diet composition (compiled in Turner and Kelley 1966), which have formed the basis of estuarine food web models ever since (Moyle 2002). Stevens (1966) found striped bass heavily cannibalized their own kind, particularly during spring and summer, then increased their use of threadfin shad, which at the time was a newly introduced species, during fall and winter.

The likely reasons for the decrease in cannibalism in our observations are the decline of striped bass abundance (Kimmerer and others 2000) and the introduction of forage species such as yellowfin goby and inland silverside that are now very abundant (Moyle 2002).

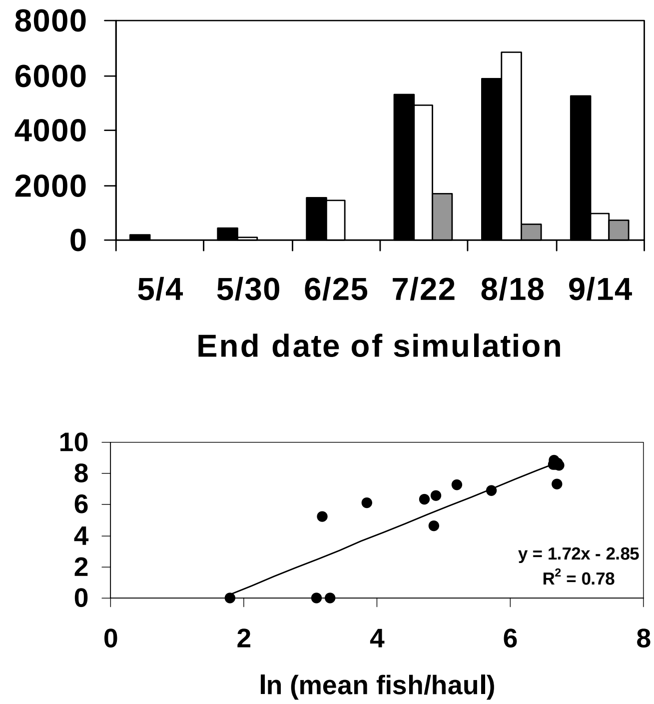

Figure 2 Combined striped bass/largemouth bass fish-consumption indices (relative mean daily fish consumption in grams) for April-September 2001 (panel A). Black bars are central Delta, white bars are lower Sacramento River, and gray bars are Liberty Island (Yolo Bypass). Panel B is the linear regression relationship between the natural log transformed fish consumption indices and the natural log transformed observed number of fish per seine haul (excluding striped bass and largemouth bass) for the same times and places

Predation Patterns are Controlled by Production of Prey Fishes

Our preliminary evidence suggests fish consumption by age-0 and age-1 striped bass and largemouth bass increases with increasing availability of prey fish (Figure 2). In the San Francisco Estuary and Delta, the abundance of many age-0 fishes (those most vulnerable to age-0 and age-1 piscivores) is driven by freshwater flow (Brandes and McLain 2001; Meng and Matern 2001; Kimmerer 2002). Therefore, seasonal and interannual variation in the physical environment is primarily responsible for “setting up” a prey base for young predators. In turn, both young (age-0 and age-1) and older piscivores respond to changes in the relative abundances of prey fishes by increasing consumption of abundant species (Table 5; see Hartman and Margraf 1992; Buckel and others 1999 for examples from other systems).

Prey switching can cause density-dependent mortality in prey populations (Hixon and Carr 1997; Buckel and others 1999). However, we caution that the “density-dependent” prey use we observed in 2000-2001 does not necessarily result in density-dependent prey mortality. For instance, the production of a prey species in a given year may outstrip the ability of the predator populations to reduce it. Alternatively, sequential recruitment and/or immigration of different species (Meng and Matern 2001) could cause predators to switch to the newly available and more abundant prey before a species which had been available earlier was significantly reduced.

Assessing the Role of Predators in the Estuary

It is interesting that evidence for density-dependent mortality is accumulating for local estuarine fishes (Table 7). Whether or not predatory fishes are a mechanism for density-dependence, density-dependence is often observed in fish populations (Beverton and Holt 1957), and is not in itself a reason to be concerned for the long-term viability of affected species. Because it is beyond the scope of this study to determine whether predatory fishes contribute to prey fish density-dependence in the San Francisco Estuary, IEP has funded a second study (Kimmerer and Nobriga 2002) to assess the “population-level” impacts of striped bass and largemouth bass.

Control of Egeria densa May Help to Reduce Predation Rates

Given the success of striped bass in the San Francisco Estuary, and its similarity in flow response to native fishes of concern (Kimmerer 2002), it is doubtful that much can be done to mitigate its predation impacts. In contrast, it is possible that large-scale removal of *E. densa* (if possible), or design of SWH restoration projects to limit growth of *E. densa*, may provide a means to control largemouth bass recruitment. Because no currently ESA-listed native fishes preferentially use *E. densa*-dominated SAV habitats (Simenstad and others 2000), suppressing *E. densa* may provide a means to non-native piscivores that does not substantially affect native species of concern.

Table 7 Summary of flow-abundance relationships and evidence for density-dependent mortality in selected species of fishes.

Common name	*Scientific name*	*Outflow relationship*[a]	*Evidence for density-dependent mortality*
Striped bass	*Morone saxatilis*	age-0 survival index (-)correlated with X2	MWT abundance indices (+) correlated with mortality[c]
Delta smelt	*Hypomesus transpacificus*	townet abundance index (-)correlated with X2[b]	MWT abundance (+) correlated with mortality[d]
Splittail	*Pogonichthys macrolepidotus*	MWT abundance index (-)correlated with X2	nonlinear relationship between combined SWP/CVP salvage of age-0 and age-1 the following year[e]

[a] Based on Jassby and others (1995) and/or Kimmerer (2002)

[b] 1981-2000

[c] Kimmerer and others (2000)

[d] Brown and Kimmerer (2001)

[e] DWR unpublished data

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Landscape-level Hydrologic Variation in the Yolo Bypass: Implications for River Restoration

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Introduction

Although the hydrologic regime is the primary factor determining the structure and function of river-floodplain systems (Junk and others 1989), detailed descriptions of basic hydrologic characteristics such as surface area, depth, residence time, and velocity are lacking at ecologically relevant temporal and spatial scales. Floodplain habitat is particularly difficult to model because of extreme hydrologic variability. In the absence of high resolution data on both hydrologic and biological processes, modeling studies of large river-food web dynamics (e.g., Power and others 1995) have relied instead upon generalized hydrologic patterns. To help address gaps in our knowledge about the functioning of river-floodplain systems, we used a simple landscape-level hydrologic model for a 60 km reach of the lower Sacramento River and its adjacent floodplain, the Yolo Bypass (Figure 1). Although the Sacramento River and Yolo Bypass are highly altered (Sommer and others 2001a), this river-floodplain system had major advantages for our evaluation: (1) the river channel is physically separated from its floodplain by a levee, allowing a well-defined comparison of factors within each landscape; and (2) we had sufficient data on the topography and hydrology to simulate physical descriptions on daily time scales. We focused on a landscape level analysis (e.g., 10-100 km reaches) because this scale is perhaps the most relevant for addressing resource management issues (Fausch and others 2002)

Methods

Because of the difficulty in directly measuring variables such as water velocity, depth and surface area in a large river-floodplain systems, we used a simple model to simulate daily trends in several physical variables at the landscape-scale for three hydrologically diverse years: 1998, an extreme high flow year; 2000, a moderately high flow year; and 2001, a dry year (Figure 2a). The model treated each of the two study areas as “reservoirs” described by (1) basin geometry; and (2) flow and stage time series. The Yolo Bypass floodplain geometry was developed from 200 cross-sections collected at 300 m intervals by the U.S. Army Corps of Engineers. Sacramento River geometry was taken from 75 cross-sections along the reach adjacent to Yolo Bypass (U.S. Geological Survey, unpublished data). We obtained mean daily stage and flow data from five gauging stations in Yolo Bypass and four stations in the Sacramento River (USGS, California Department of Water Resources). For each date in the time series, the model used linear interpolation between the gauging stations to estimate the stage at each cross-section. The estimated stage value was then used to calculate each cross-section’s conveyance characteristics: area, width, and wetted perimeter. The daily results for each cross-section were used to estimate total inundated surface area, mean velocity and hydraulic residence time for each study area (reach). We also calculated the total surface area <2 m depth as an index of shallow water habitat. Our selection of the <2 m depth index was somewhat arbitrary as there are multiple shallow water habitats; however, the 2 m threshold has some biological relevance as it is an accepted criteria defining wetland littoral zones (Cowardin and others 1979). It is also important to note that the velocity and hydraulic residence time calculation represents idealized rather than actual values. Our hydrologic model relied on a simple mass balance approach that did not account for daily tidal effects (i.e., “routing”), a particularly important factor during low flow conditions. To highlight this limitation, we will refer to these variables as idealized hydraulic residence time and idealized mean velocity. Nonetheless, we believe that the model provided a useful index of relative differences between the study areas and years.

The large scale of the landscape made it too difficult to validate all of the simulated variables. As a partial validation of the model, we estimated total inundated area for Yolo Bypass using 1:24,000 scale area aerial photographs for three days. We took aerial photographs of the entire floodplain, digitized, then georeferenced to satellite imagery. We delineated inundated area for each set of images using a GIS program (ARCVIEW), then compared total area to model estimates for the same dates.

Major Findings

Model Results Were Reasonably Similar to Measured Surface Area. Peak inundation of Yolo Bypass occurred during February 1998, when the total simulated surface area of 23,500 ha was close to our 24,000 ha estimate of basin surface area from aerial photographs (Figure 2b). The model and aerial photograph estimates (21,000 ha) were equivalent for March 2, 1998. The model was somewhat less accurate for April 28, 1998, when the simulated area of 6,750 was higher than the 5,050 ha calculated from aerial photographs, and for February 28, 2001, when the simulated area of 10,200 ha was higher than the 7,820 ha from aerial photographs.

Inundation of Yolo Bypass Dramatically Increases Total Surface Area for Aquatic Species in the Delta. During 1998 and high flow pulses in 2000 and 2001, the total inundated surface area of Yolo Bypass exceeded that of the Sacramento River (Figure 2b). Surface area in the Yolo Bypass closely followed the flow peaks, with successively smaller amounts of inundated area for each of the study years. By contrast, the total surface area in the Sacramento River varied little among months and years. The floodplain results were particularly striking during January 1998, when the total inundated area of Yolo Bypass was approximately equivalent to the wetted area of all Delta channels (Sommer and others 2001a). The model results demonstrate that when Sacramento River floods into Yolo Bypass, there is a substantial increase in surface area for aquatic species. This surface area effect is a major reason why modeling studies by Jassby and Cloern (2000) concluded that floodplain inundation increases Delta primary production, and why Sommer and others (2001b) found high levels of benthic invertebrates (chironomids) during Yolo Bypass flood events.

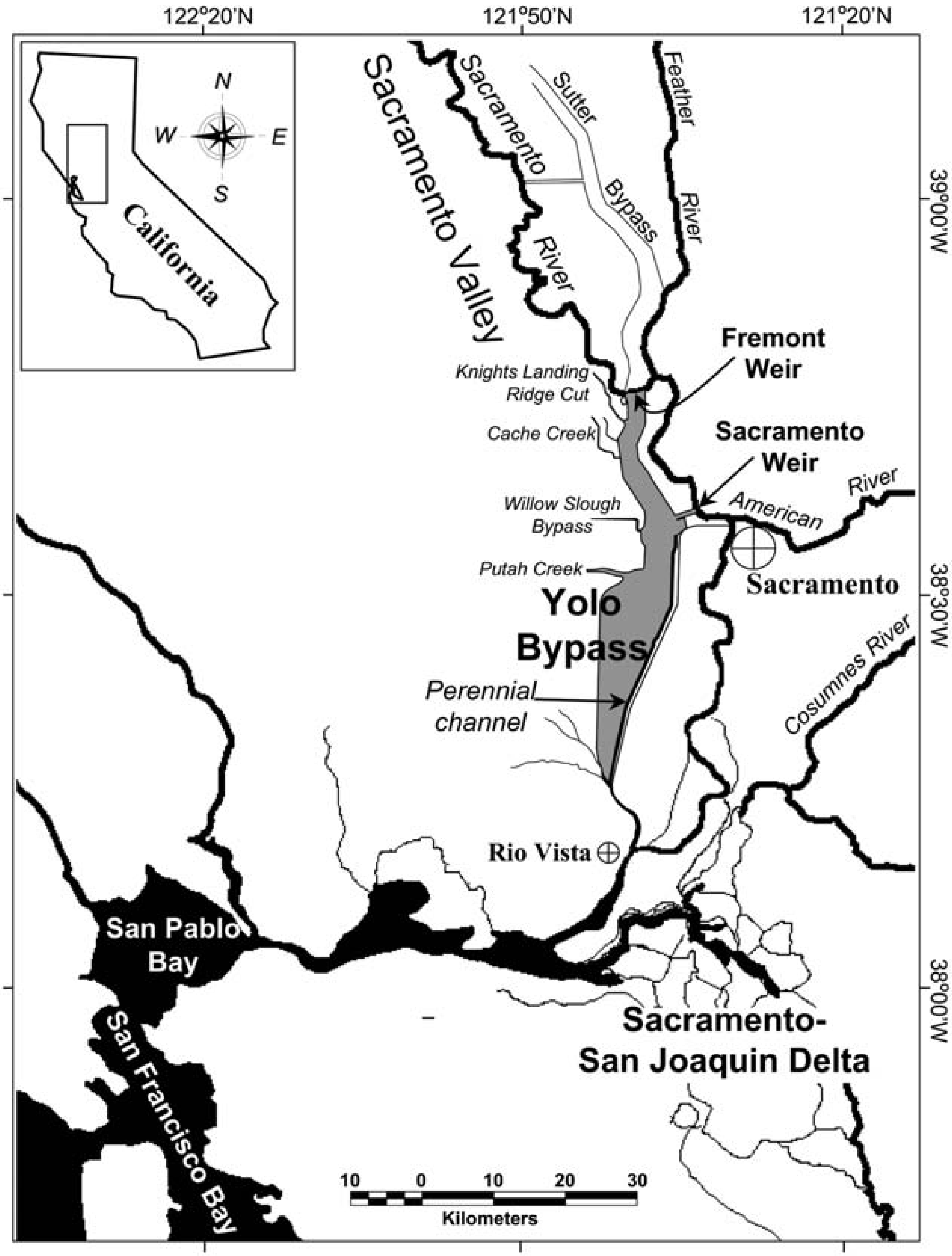

Figure 1 Location of Yolo Bypass in relation to the San Francisco Estuary and its tributaries

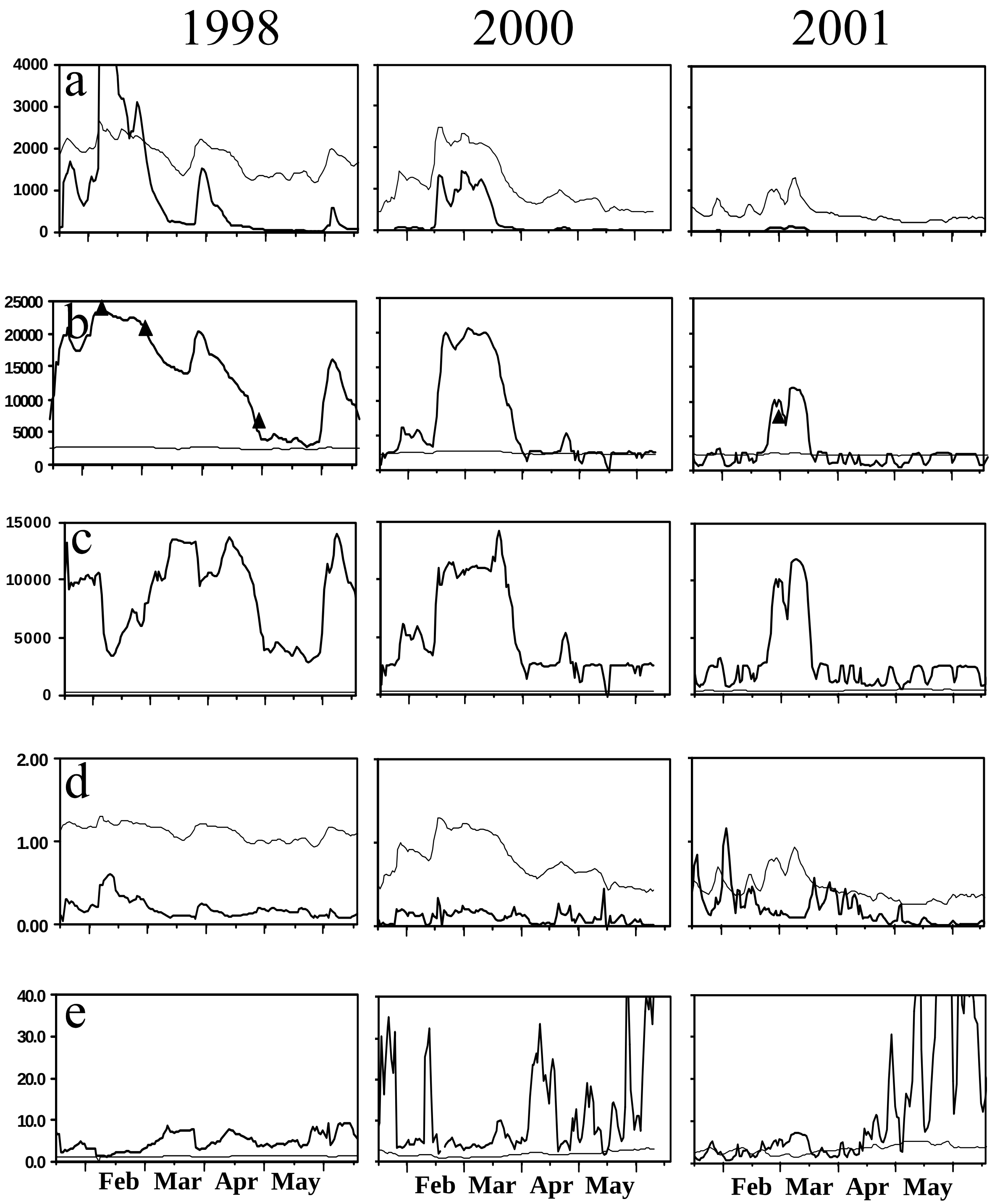

Figure 2 Results of hydrologic simulations and water temperature for the Yolo Bypass (thick line) and Sacramento River (thin line) during winter and spring of 1998, 2000, and 2001. (a) Mean daily flow (m^3 /sec); (b) simulated total surface area (ha); (c) simulated total surface area <2 m depth (ha); (d) idealized mean water column velocity (m/sec) and; (e) idealized mean hydraulic residence time (days). Flooded area on the Yolo Bypass, estimated from aerial photographs, is indicated with triangular symbols.

Even Minor Inundation of the Yolo Bypass Creates Relatively Large Areas of "Shallow Water Habitat": In the Sacramento River, our index of shallow water habitat, the estimated total surface area <2 m depth, remained at a level of less than 500 ha throughout the study (Figure 2c). The total surface area <2 m was generally an order of magnitude higher in Yolo Bypass than Sacramento River during the flood events. One of the more surprising results was that modest flow events, such as February and March of 2001, resulted in peak inundation of over 10,000 ha of area <2 m in Yolo Bypass. Moreover, a greater portion of the total inundated area of Yolo Bypass is in the "shallow" range. The total area <2 m comprised 7% to 17% of the total surface area of the Sacramento River, whereas this shallow area comprised 50% to 100% of the total surface area in Yolo Bypass except during the February 1998 flood peak (Figure 2b,c). These modeling results clearly show that inundation of the Yolo Bypass can create vast areas of spawning and rearing habitat for splittail (Sommer and others 1997; Sommer and others 2002), and rearing habitat juvenile salmon, which are typically associated with shallow depths (Everest and Chapman 1972). Note, however, that in 2001 the large area of shallow floodplain habitat was largely unavailable to juvenile salmon migrating down the Sacramento River because the river did not spill into Yolo Bypass; all of the observed flooding was from smaller tributaries to the floodplain.

Water Velocities are Typically Much Lower in Yolo Bypass than Sacramento River, Likely Improving Conditions for Salmonid Rearing. Simulations of idealized mean water velocity tracked flow trends at each location; however, the estimates were at least two to three times greater in the Sacramento River than the Yolo Bypass in all years except 2001 (Figure 2d). Idealized mean velocity in Yolo Bypass was actually highest in winter and spring of 2001, the driest water year, when all of the Yolo Bypass flow was confined to the floodplains perennial channel ("Toe Drain") except for a short February-March pulse. These model results suggest that Yolo Bypass typically provides more suitable velocities for salmon fry rearing than the Sacramento River because early life stages of young salmon are typically associated with low velocity habitat (Everest and Chapman 1972).

Hydraulic Residence Time Was Much Longer in Yolo Bypass Than Sacramento River, Which May Benefit Lower Trophic Levels. Idealized hydraulic residence time showed very little variation in the simulations for Sacramento River, remaining less than 5 days in all years (Figure 2e). Idealized hydraulic residence times were much more complex for Yolo Bypass, and substantially longer than in the Sacramento River during all months except part of 2001. The longer hydraulic residence times likely enhance lower trophic levels, particularly phytoplankton, which show higher production on the floodplain than in the river channel (Sommer 2002). Zooplankton such as cladocerans may also benefit as their growth rate in the estuary appears closely linked with phytoplankton biomass (Mueller-Solger and others 2002).

Implications for Restoration

The modeled variables including surface area, velocity and residence time provided insight into why inundation of Yolo Bypass from Sacramento River enhances production of several trophic levels (Jassby and Cloern 2000; Sommer and others 2001a). Stimulation of lower trophic levels through floodplain restoration would clearly benefit species that reside in the floodplain or seasonally migrate through the landscape. While we observed major increases in the availability of habitat for aquatic species in years with extensive floodplain inundation, there is poor river-floodplain connectivity in dry years such as 2001. In these drier years, migratory fish do not have access to seasonal shallow rearing habitat, and there is little opportunity for floodplain primary and secondary production to subsidize the downstream reaches of the estuary. Floodplain inundation may therefore help to explain, in part, why the abundance of many organisms shows a positive relationship with flow (Jassby and others 1995). Given the strong effect of relatively small-scale inundation events on ecologically relevant variables such as floodplain surface area and hydraulic residence time, we predict that even modest improvements in river-floodplain connectivity could enhance nursery habitat for native fish (e.g., Chinook salmon and splittail) and provide food web support to the estuary.

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CALFED Activities

Report from the CALFED Science Program Workshop on Water Operations and Environmental Protection in the Delta: Scientific Issues.

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The CALFED Science Program has initiated a series of issue-based workshops. The goal of this workshop series is a balanced discussion among policy makers, stakeholders, and scientists aimed at characterizing the scientific issues underlying various forms of use, conservation, and management strategies affecting the San Francisco Estuary and associated watersheds. A primary objective is to explain the current state of scientific understanding and consider how the CALFED programs, CALFED agencies, existing facilities and operations, and policy decisions depend on and use this knowledge. From these discussions, recommendations to further develop critical knowledge and to integrate knowledge into existing state and federal programs and projects will be presented.

The first workshop in the series was held on April 22-23, 2002 in Sacramento, California. This workshop focused on issues associated with water operations and environmental protection in the San Francisco Estuary. A number of technically complex issues are associated with balancing water allocations among environmental, urban, and agricultural uses in the estuary and its watershed. This workshop was designed to present and discuss a comprehensive set of those issues, at a level of detail policy makers need to make informed decisions and stakeholders need to understand the scientific basis of those decisions. Major findings from this workshop follow:

Strong government support. There is high-level support within state and federal governments for CALFED and the Record of Decision. A complex program such as CALFED will require an investment in science to provide information important in making the necessary policy decisions. While acknowledging the importance of science, it is a major challenge for both the state and federal governments to keep funding at a high level. Going forward, it is important that the science reflect what is most needed.

The X2 outflow standard: genesis and next steps. The X2 outflow standard is considered very robust because it was developed in a science-based process, and thus reflects a strong ecological basis. It is directly relevant to several policy issues, and includes a dynamic implementation process. Management through the X2 standard is largely based on relationships between the abundance or survival of various organisms and X2. However, elucidating the mechanisms underlying the relationships is the essential next step to examine efficiencies in the application of the X2 standard and the consequences of changes that are likely to occur as a result of CALFED actions and climate change.

New interest and information from an old facility. The Delta Cross Channel (DCC) has been the subject of intense studies over the last two years. The purpose of these collaborative and interdisciplinary studies is to better understand the influence operation of the DCC has on hydrodynamics, water quality, and fish passage. Constructed in 1950-1951, the DCC provides a shortcut for Sacramento River flows to the South Delta for export and aids in meeting several salinity standards. Closure of the DCC for fish is largely based on the migration patterns of Chinook salmon through the Delta. Initial results from recent investigations show DCC flows are strongly influenced by the tides, but there is a dramatic change in the hydrodynamics at the DCC: flows upstream of the DCC are largely riverine (unidirectional), while flows downstream of the DCC are tidal (bi-directional). It is now thought that salmon entrainment into the DCC largely depends on the flow field the fish encounter at the time of arrival. Results from these studies will help to determine optimal operations of the DCC to ensure water supply reliability with minimal effects to water quality and fish migration. The DCC study methods also will be useful in the evaluation of other CALFED Delta projects like a through-delta facility or the South Delta Temporary Barriers.

Conceptualizing water operations and environmental protection: how should we measure the results? A working conceptual model for water operations and environmental protection shows that CALFED uses a number of tools to manage water operations and meet ecosystem commitments. The tools are quite diverse and take the form of programs and regulatory requirements. These tools are generally used in combination, so it is difficult to separate the effects of any one tool from effects of the others. Measures of ecosystem performance reflect the aggregated effects of all actions; thus, it will be difficult to test the assumptions or hypotheses about individual tools in isolation. Assessments should focus on net effects of aggregated actions to changes in the overall condition of the ecosystem.

The Environmental Water Account — thoughts and information on the newest environmental protection tool. Discussions between stakeholder and agency representatives led to the Environmental Water Account (EWA). Application of the EWA was seen as a way to reduce or avoid such conflicts by stabilizing water supplies, while giving the fish protection agencies direct control over the water resources that would be used to make up for curtailments in pumping. The EWA allows for some adaptive management and integration of policy and science, at least in a broad sense. One challenge for implementation of the EWA is that the range of uncertainty for key factors such as hydrologic conditions and the necessity for fish actions increases during the time contract commitments for water are being secured. An independent panel of experts reviewed the first year of EWA implementation, and identified many positive factors including successful implementation, management, and decision-making. The panel suggested greater human intellectual investment, increasing management flexibility, and increasing the scientific basis for EWA decisions and actions are all key to the longer-term success.

Bringing science to bear on our knowledge of living resources and the effects of water diversions. Several presentations focused on the science challenges in understanding the population biology of fish species of concern, and managing water diversions to protect the estuary environment and its living resources. A central question was "is reducing the effects of the export pumps the best use of environmental water?" Reductions in the amount of water exported can reduce the number of individual fish lost from the system, but it is a challenging question as to whether protecting individual fish is the same as restoring fish populations. Ultimately it will be important to integrate a more sophisticated population level approach into the present strategy of evaluating abundance indices, migration patterns, and "take" as tools for managing water operations or making comparisons among alternative actions.

Current understanding of delta smelt population dynamics suggest there is a substantial stochastic element to what determines the abundance of this species. The potential consequences of serial events must be factored into any population model. One conceptual model is that delta smelt must withstand an environmental gauntlet and it is the myriad of factors within this gauntlet that regulate the population size. The remaining science challenges for delta smelt require greater understanding of: (1) the basic biology; (2) population dynamics; and (3) cause/effect relationships.

The largest outstanding issue relative to understanding salmon population dynamics is the inability to consistently estimate natural production. In practice, the success of recovery and restoration actions will be measured in terms of natural production, whether it is high enough to sustain populations at levels meeting ESA requirements and allowing for some use of the salmon resources. The ability to confidently estimate natural production is critical to determining the success of recovery or restoration actions.

A complete written summary of the information presented at this workshop along with the questions, answers and comments occurring during the workshop is available at http://calfed.ca.gov/Programs/Science/adobe_pdf/Workshop_Operations_Summary_April21-22-02.pdf

Scientific Community News

New Project Leader Selected for the U.S. Fish and Wildlife Stockton Office

We are very pleased to announce the selection of Dr. Russell J. Bellmer as the new Project Leader for the Stockton Fish and Wildlife Office. His transfer effective date was November 2, 2002. Russ was the Restoration Manager for the Damage Assessment and Restoration Program and Restoration Research Program Manger with NOAA Fisheries (National Marine Fisheries Service) in the NOAA Restoration Center in Silver Spring, Maryland. He has extensive experience as Senior Scientist in both the Habitat Conservation and Endangered Species programs, and has been involved nationwide in numerous fish and wildlife resource activities, including applied ecological research, fisheries habitat restoration project implementation, marine non-native invasive species issues, and Natural Resource Damage Assessment case activities. Russ also has prior experience as a Marine Ecologist in the Washington Level Review Center, New England Division, and Los Angeles District with the Corps of Engineers. He has taught biology, ecology, and marine science at the college and university level part-time and has published in the area of applied ecology. Russ is a California native from the San Francisco Bay area, SCUBA diving instructor, and underwater photographer. He holds a Ph.D. in Marine Ecology from Clark University in Worcester, MA. He completed a Master of Science in Environmental Science at California State University Dominguez Hills and a Bachelor of Science Degree in Biological Sciences at the University of California Irvine. Russ's wife is an interior designer and they have two children. Please welcome Russ and his family.

For a review of the STFWO monitoring program, see the Delta Juvenile Fish Monitoring Program at http://www.delta.dfg.ca.gov/usfws/

Meeting Review

The Chinese Mitten Crab Workshop in 2002 Focuses on Advances in Research and Management of an Invasive Crustacean in the San Francisco Estuary

Deborah A. Rudnick (University of California at Berkeley), drudnick@nature.berkeley.edu

The Chinese mitten crab 2002 Workshop was an opportunity for scientists and managers to present and discuss the latest information regarding the ecology and impacts of this invasive species. The meeting was convened by the Chinese mitten crab Project Work Team (CMC PWT) a subgroup of California's Interagency Ecological Program (IEP). In 1999, the first mitten crab workshop took place in Sacramento, California. The PWT decided it would be useful to hold another workshop, as substantial research and management activities had taken place in the intervening three years. Thirty participants attended the meeting hosted by the Contra Costa Campus of California State University Hayward. Attendees came from universities; local, state, and federal government agencies; and non-profit institutions in California, the Pacific Northwest, and Europe.

This three-day meeting provided talks, a forum for discussion, and site visits to examine habitats and effects of the mitten crab. Conference sessions included distribution, abundance, and habitat use; monitoring and sampling methods; ecological and economic effects; the development of a life history model; and management and control. A brief synopsis of the topics discussed shows that researchers have made substantial progress in understanding the spread of this species and documenting its effects.

Distribution and Abundance

Mitten crab abundance has fluctuated widely in the decade that the crab has been present in the San Francisco Estuary. Since the peak of abundance in 1998, a decline in 1999 and 2000 was followed by an increase in all collections of the crab for all routinely tracked data sources in 2001. The range of the mitten crab in the freshwater tributaries to the estuary followed a similar pattern with abundance. Preliminary 2002 data suggests a smaller population size this year. A look at European population dynamics of the crab shows many patterns similar to what we have seen in California, including rapid rates of increase in abundance and distribution, and fluctuating population sizes.

Multiple studies and monitoring efforts are confirming that juvenile mitten crabs have few limitations in terms of habitat use, as they are found to be associated with an enormous diversity of substrates, temperatures and stream velocities. Two studies from the Department of Water Resources suggest that submerged aquatic vegetation (SAV) is a favorable habitat for juvenile mitten crabs, with high numbers of crabs found in association with this vegetation.

Monitoring and Sampling Methods

Mitten crab researchers have employed a wide variety of sampling techniques to track the crab's distribution and abundance and collect samples for research. Among the successes in sampling have been the opportunities to collaborate with ongoing monitoring studies, such as long-term trawling efforts, by agencies and institutions already conducting research in the San Francisco Bay. The Department of Fish and Game, the Marine Science Institute, and UC Davis are among those institutions able to provide vital data through their consistent collection of the crab since the mid-1990s. The U.S. Fish and Wildlife Service has incorporated public participation by instituting a call-in hotline and mailers. These public outreach methods are being widely used in Oregon and Washington to engage the public and agencies in early detection activities.

However, there are also several challenges to monitoring and collection of this species. Attempts by multiple researchers to use baited traps have met with little success, and seining does not appear to be effective. Trawl data may not accurately represent abundance, as many crabs may be able to avoid the trawl, and because trawls cannot effectively sample very shallow or highly vegetated areas that may contain high densities of this species. Artificial shelter traps, which use PVC tubes to provide crabs with a place to hide, have been shown to be a highly effective method of collecting juvenile crabs in a variety of habitats.

Ecological and economic impacts

The mitten crab is causing a wide array of ecological and economic alterations and effects. Several of these effects were discussed at the workshop. At the federal and state fish facilities in the Delta, efforts are underway installing and testing a variety of control methods to keep crabs out of the facilities. Low numbers of crabs in the past few years have been both a boon to the facilities in keeping fish mortality low, as crab numbers are not high enough to crush the fish in the holding tanks, but have provided minimal opportunity to test the installed barriers. Other physical effects of the crab include burrowing activities. A study by USGS is underway to examine the burrow morphology of the crab and quantify sediment associations and effects. The researchers shared resin casts of some large and intricate burrows that were impressive evidence of the mitten crab's ability to alter sediment morphology and stability.

Recent advances in detecting effects are also underway in a study from the USGS to examine mercury bioaccumulation in the mitten crabs. To date, only one small study has been conducted by the California Department of Health Services to examine contaminant loads. As California's mitten crabs are eaten by a wide variety of wildlife as well as by some people, participants agreed that much more needed to be understood about toxin loading of this species.

Two studies from the Department of Water Resources and UC Berkeley are examining effects of mitten crabs on benthic food webs in bay area watersheds. Gut content analysis and experimental enclosures have been employed to examine feeding habits of the crab. Preliminary data suggests the crabs feed on a wide variety of plant and invertebrate animal matter, and that feeding habits may vary with local community composition (for example, SAV may be a larger part of the crab's diet in North Bay streams than in the South Bay).

Life history

Several members of the CMC PWT and other agency and institution staff are engaged in elucidating the complex life cycle of the Chinese mitten crab in California. At the workshop, speakers emphasized the importance of understanding this life cycle as an essential precursor to quantifying this species' effects, predicting population dynamics, and preparing management plans. Current projects discussed at the workshop include understanding larval recruitment and settlement dynamics; describing morphology and growth rates; and exploring reproductive development and cues for downstream migration. Over the past year, a subgroup of the PWT has been developing a working life history model that incorporates many of these recent advances in understanding. Workshop participants had a lively discussion about the proposed model and its implications for population dynamics of the crab.

Management and Control

Management activities for a species which reproduces quickly, spreads rapidly over a wide range of freshwater and estuarine habitats, and achieves high levels of abundance in a short period of time, are admittedly a challenge. However, many opportunities for management were discussed. The National Mitten Crab Management Plan, created by the National Aquatic Nuisance Species Task Force, is a document that aims to identify areas at high risk of invasion by the mitten crab and prioritizes area. Participants were encouraged to provide commentary to the draft of this plan. Early detection and monitoring for the crab is underway in the Pacific Northwest (see monitoring section above). The best opportunity for active control of the crab may be during the mass migration of adults to their breeding grounds in the fall. A pilot study conducted by UC Santa Barbara collected over 11,000 crabs from a South Bay tributary over a period of six weeks using a modified fish sampler. Participants discussed the need for more biological information and high levels of coordination that would be necessary to conduct longer-term, larger scale studies of these types of management activities.

Field Trips

Two field trips were offered at the workshop: one to the federal fish salvage facilities in the Delta, where mitten crabs entrained in holding tanks have caused extensive damage to fish, and another to a South Bay stream to look at mitten crab habitat and burrowing activities. The first field trip brought attendees to the Tracy Fish Collection Facilities, where staff explained the crab's deleterious effects on fish salvage activities, and the considerable expense and time that has been spent to find ways to keep the crabs from entering these facilities (Figure 1).

Figure 1 Leif-Matthias Herborg, a visiting researcher from England, tries his hand at mitten crab burrow excavation during the workshop's field trip to south San Francisco Bay to look at mitten crab sampling techniques.

The second field trip offered the opportunity for participants, some of whom had never seen a live Chinese mitten crab in California, an opportunity to see the crabs in their habitat of a South Bay freshwater stream. Participants were shown passive trapping methods and transect methods to estimate abundance of burrowing crabs (Figure 2). A quick (15 minute) collection by eight field trip participants of small juvenile crabs from this tidally influenced site yielded over 90 crabs, indicating that at least one South Bay population of this crab is still quite abundant!

Figure 2 At the U.S. Bureau of Reclamation's Fish Salvage Facility in Tracy, California, workshop participants learn about what is being done to keep crabs out of fish holding tanks while observing a tank full of live mitten crabs collected at the facility

Conclusions

The 2002 Chinese mitten crab workshop was an excellent opportunity to discuss current research, identify gaps in our knowledge and discuss next steps in research and management activities for this species. We have gained knowledge about several aspects of the crab's ecology, including its feeding habits, habitat associations, and population dynamics. We are pursuing more information about its effects, including toxin accumulation, burrowing effects, and mitigation for fish facility impacts. The workshop also helped participants identify areas in need of more effort, such as many aspects of the life cycle (growth and reproductive requirements), effectiveness of outreach methods, and further tests of control activities. The conference stimulated discussion and collaboration among researchers and managers to work together on many of these questions.

The CMC PWT intends to continue these workshops as a way to advance our knowledge and stimulating thinking about the management of this species. If you would like information about future meetings, or would like a copy of the abstracts of this meeting (which will eventually be available through the IEP website), please contact the author at drudnick@nature.berkeley.edu.

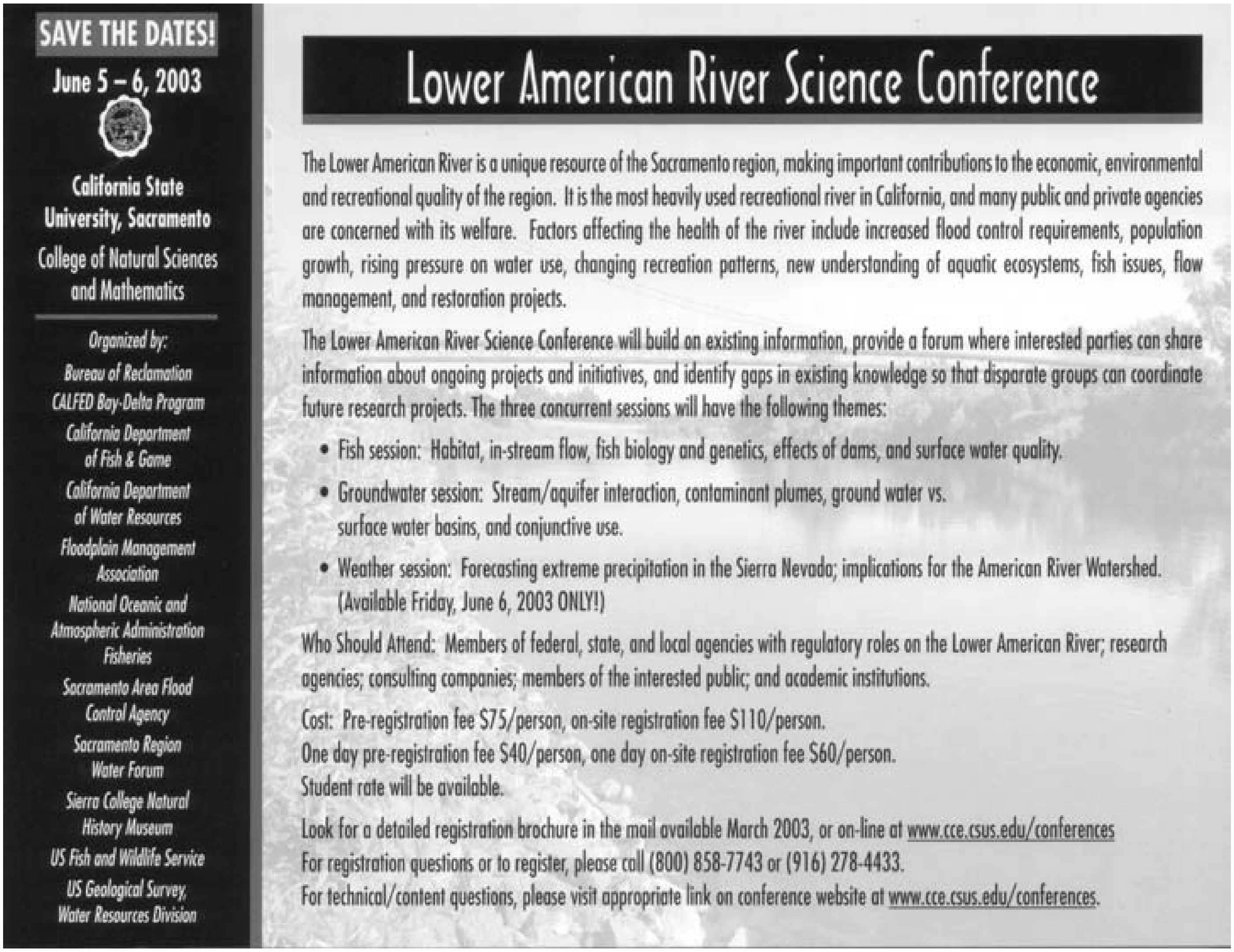
On the Horizon

Early Life History of Fishes in the San Francisco Estuary and Watershed Symposium and Proceedings Volume

Fred Feyrer (ffeyrer@water.ca.gov, DWR), Larry Brown (USGS), Jim Orsi (DFG), Randy Brown (CalFed)

This IEP and CALFED supported symposium will take place at the 2003 American Fisheries Society Larval Fish Conference at UC Santa Cruz, August 20-23. We anticipate the symposium taking the form of two afternoon sessions scheduled on consecutive days at the conference, with about 25 presentations. Twenty of the presentations have been submitted as manuscripts for publication in the proceedings volume, which will be published by the American Fisheries Society, and are all currently in various stages of review and revision. For more information visit http://iep.water.ca.gov/2003_elh/

Save the Dates



SAVE THE DATES!

June 5 – 6, 2003

California State University, Sacramento

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Bureau of Reclamation
CALFED Bay-Delta Program
California Department of Fish & Game
California Department of Water Resources
Floodplain Management Association
National Oceanic and Atmospheric Administration Fisheries
Sacramento Area Flood Control Agency
Sacramento Region Water Forum
Sierra College Natural History Museum
US Fish and Wildlife Service
US Geological Survey, Water Resources Division

Lower American River Science Conference

The Lower American River is a unique resource of the Sacramento region, making important contributions to the economic, environmental and recreational quality of the region. It is the most heavily used recreational river in California, and many public and private agencies are concerned with its welfare. Factors affecting the health of the river include increased flood control requirements, population growth, rising pressure on water use, changing recreation patterns, new understanding of aquatic ecosystems, fish issues, flow management, and restoration projects.

The Lower American River Science Conference will build on existing information, provide a forum where interested parties can share information about ongoing projects and initiatives, and identify gaps in existing knowledge so that disparate groups can coordinate future research projects. The three concurrent sessions will have the following themes:

- Fish session: Habitat, in-stream flow, fish biology and genetics, effects of dams, and surface water quality.
- Groundwater session: Stream/aquifer interaction, contaminant plumes, ground water vs. surface water basins, and conjunctive use.
- Weather session: Forecasting extreme precipitation in the Sierra Nevada; implications for the American River Watershed. (Available Friday, June 6, 2003 ONLY!)

Who Should Attend: Members of federal, state, and local agencies with regulatory roles on the Lower American River; research agencies; consulting companies; members of the interested public; and academic institutions.

Cost: Pre-registration fee $75/person, on-site registration fee $110/person.
One day pre-registration fee $40/person, one day on-site registration fee $60/person.
Student rate will be available.

Look for a detailed registration brochure in the mail available March 2003, or on-line at www.cce.csus.edu/conferences
For registration questions or to register, please call (800) 858-7743 or (916) 278-4433.
For technical/content questions, please visit appropriate link on conference website at www.cce.csus.edu/conferences.

Articles Published in Volume 15 of the IEP Newsletter

Number 1, Winter 2002

Introduced Palaemonid Shrimp Invades the Yolo Bypass Floodplain
Steven Zeug, szeug@water.ca.gov; Gavin O'Leary; Ted Sommer; Bill Harrell; and Fred Feyrer (DWR)

***Daphnia lumholtzi* Detected Again**
Jim Orsi (DFG, retired), jjorsi@aol.com

Water Year Hydrologic Classification Indices for the Sacramento and San Joaquin Valleys
Karen Gehrts (DWR), kagehrts@water.ca.gov

Sea Grant Study Finds Chinese Mitten Crabs Appear Free of Human Parasite Lung Flukes
Adapted from a news release submitted by Gerald Hatler (DWR). Contact: Carrie Culver, National Sea Grant College Program, c_culver@lifesci.ucsb.edu

A Survey to Examine the Effects of the Chinese Mitten Crab on Commercial Fisheries in Northern California
Deborah Rudnick and Vincent Resh (UC Berkeley, Department of Environmental Science, Policy and Management), drudnick@nature.berkeley.edu

Water Level, Specific Conductance, and Water Temperature Data, San Francisco Bay, California for Water Year 2000
Paul A. Buchanan (USGS), buchanan@usgs.gov

Fall Dissolved Oxygen Conditions in the Stockton Ship Channel for 2000
Casey Ralston and Stephen P. Hayes (DWR), cralston@water.ca.gov

Assessing Fish Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison Among Native and Non-Native Species
Matt Nobriga (DWR), Zoltan Matica (DWR), and Zach

Number 2, Spring 2002

Exposure of Delta Smelt to Dissolved Pesticides in 2000
Kathryn M. Kuivila and G. Edward Moon (USGS) kkuivila@usgs.gov

Adult Chinook Salmon Migration Monitoring at the Suisun Marsh Salinity Control Gates, Sept.–Nov. 2001
Robert F. Vincik (DFG), rvincik@delta.dfg.ca.gov

Number 3, Summer 2002

Investing in the IEP Environmental Monitoring Program
Anke Mueller-Solger (DWR) and Zachary Hymanson (CALFED), amueller@water.ca.gov

Tidal Datum Determination for Marsh Restoration Planning
Callie Harrison and Chris Enright (DWR), callieh@water.ca.gov

DAYFLOW Program Updates
Brad Tom, Kate Le, and Chris Enright (DWR), cenright@water.ca.gov

Do Mitten Crabs Carry the Parasitic Lung Fluke?
Johnson Wang and Lloyd Hess, jwang@mp.usber.gov

Otolith Sulfur Isotope Method to Reconstruct Chinook Salmon (*Oncorhynchus tshawytscha*) Life History
Peter K. Weber, Ian D. Hutcheon, Kevin D. McKeegan, and B. Lynn Ingram; pweber@socrates.berkeley.edu1

Pulsey, Patchy Water Quality in the Delta: Implications for Meaningful Monitoring
Lisa V. Lucas (USGS Menlo Park), Tara S. Schraga (USGS Menlo Park), Cary B. Lopez (USGS Menlo Park), Jon R. Burau (USGS Sacramento), and Alan D. Jassby (UC Davis); lisalucas@usgs.gov

Zooplankton Production in Shallow Water and Channel Habitats: An Example from Mildred Island
James J. Orsi (DFG), jjorsi@aol.com

Modifications to an Agricultural Water Diversion to Permit Fish Entrainment Sampling
Zoltan Matica and Matt Nobriga (DWR), zoltan@water.ca.gov

Hymanson (CALFED), mnobriga@water.ca.gov

Revision of California Department of Fish and Game's Spring Midwater Trawl and Results of the 2002 Spring Kodiak Trawl
Kelly Souza (DFG), ksouza@delta.dfg.ca.gov

Ocean Influences on Central Valley Salmon: The Rest of the Story
Louis W. Botsford (Department of Wildlife, Fish and Conservation Biology, UC Davis)

PUBLICATIONS IN PRINT

Research Published in the Open Literature in 2002

Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39-55.

Sommer T, Conrad L, O'Leary G, Feyrer F, Harrell W. 2002. Spawning and rearing of splittail in a model floodplain wetland. Transactions of the American Fisheries Society. 131:966-974.

ERRATUM

Due to an error by U.S. Geological Survey personnel in computing the water volumes filtered by the zooplankton net, the zooplankton data in the figures in Orsi JJ. "Zooplankton production in shallow water and channel habitats: an example from Mildred Island," IEP Newsletter 15(3):27-31 (2002), should be multiplied by a factor of 3.66. This error does not affect the analysis or conclusions.

DELTA WATER PROJECT OPERATIONS

Kate Le (DWR), kle@water.ca.gov

During the July through September 2002 period, flow at the Sacramento River was higher than last year. However, San Joaquin River and Net Delta Outflow Index (NDOI) hydrologic values were about the same as last year's low flow conditions. San Joaquin River flow ranged between 30 and 40 cubic meters per second (1,000 cfs and 1,400 cfs), Sacramento flow ranged between 340 and 580 cubic meters per second (12,000 cfs to 20,600 cfs), and the NDOI ranged between 69 and 192 cubic meters per second (2,400 cfs and 6,800 cfs) as shown in Figure 1.

Export action at the SWP was higher compared to last year's pumping during this time period. CVP export action was more stable than at the SWP. The significant increases and decreases in SWP pumping during July through September 2002 were due to meeting either outflow or water quality standards, except at the end of July as shown in Figure 2.

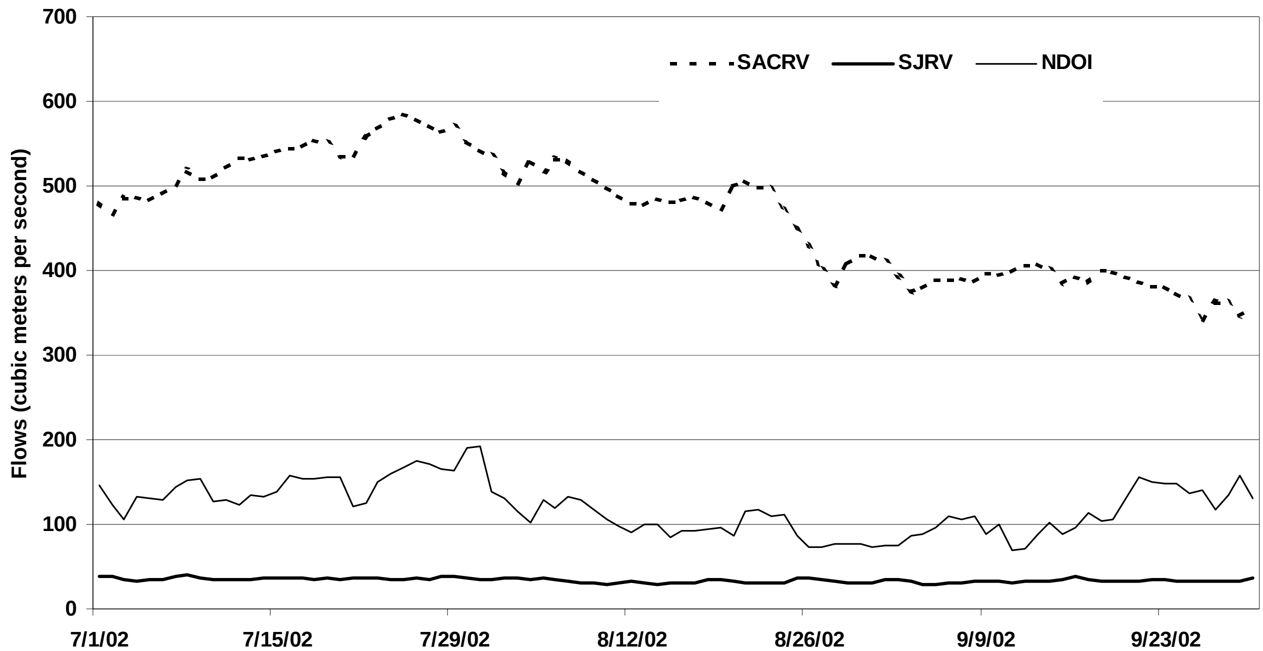

Figure 1 Sacramento River, San Joaquin River, and Net Delta Outflow Index flows, July through September 2002

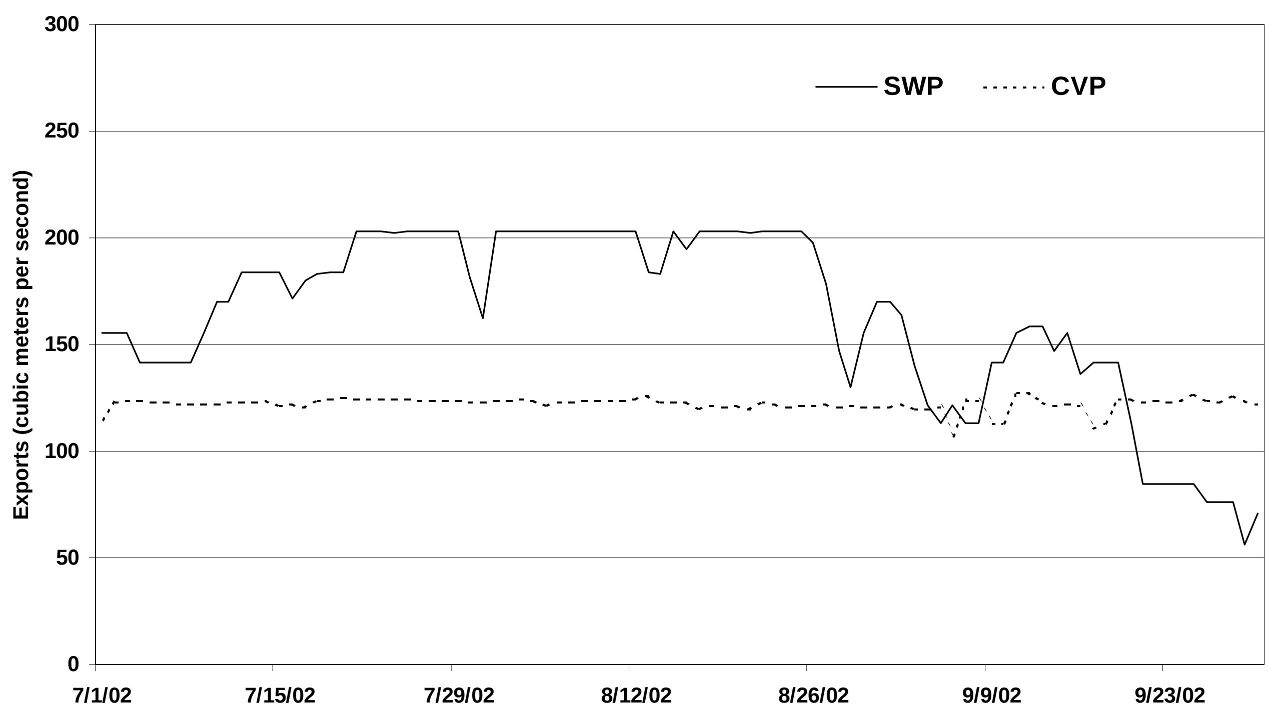

Figure 2 State Water Project and Central Valley Project Exports, July through September 2002

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

3251 S Street
Sacramento, CA 95816-7017

For information about the Interagency Ecological Program, log on to our website at http://www.iep.water.ca.gov. Readers are encouraged to submit brief articles or ideas for articles. Correspondence—including submissions for publication, requests for copies, and mailing list changes—should be addressed to Nikki Blomquist, California Department of Water Resources, P.O. Box 942836, Sacramento, CA, 94236-0001. Questions and submissions can also be sent by e-mail to: nikkib@water.ca.gov.

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

The Interagency Ecological Program for the San Francisco Estuary
is a cooperative effort of the following agencies:

California Department of Water Resources
State Water Resources Control Board
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

California Department of Fish and Game
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency

National Marine Fisheries Service

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